Associations Between Physical Fitness, Physical Activity Behaviours, Cardiovascular Health and Back Health in 6 to 8 Year old Children of Basel-Stadt

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List of Abbreviations

AVR	Arteriolar to venular ratio
CRAE	Central retinal arteriolar equivalents
CRVE	Central retinal venular equivalents
ICC	Intra-class correlation coefficient
IOTF	International Obesity Task Force
PA	Physical activity
SD	Standard deviation
WHO	World Health Organization

Summary

Background

Insufficient physical activity and physical fitness are associated with cardiovascular diseases and back pain in adults. But cardiovascular risk factors and risk factors for back pain can be detected earlier in life.

Aims

Therefore, the aim of this dissertation study was to examine associations between physical fitness, physical activity behaviour, anthropometrics and retinal vessel diameters, as a risk factor of cardiovascular disease, and spinal flexibility or spinal posture, as risk factors for back pain, in a cohort of Swiss children aged 6 to 8 years. Further, the influence of parental education, household income and nationality on physical fitness, retinal vessel diameters and risk factors for back pain was analysed. Additionally, through the Sportcheck project the physical fitness skills of all first-graders of the canton Basel-Stadt could be classified in order to arrange performance-linked additional physical education lessons. The goal was to increase children's physical activity, knowing that the motivation is higher when children are having a similar level in physical education classes.

Methods

Therefore, 1314 children conducted a 20 m shuttle run test, a 20 m sprint, a jumping sidewards and a balancing backwards test. Also height and weight were measured and the body mass index (BMI) calculated. The optional measurements of retinal vessel diameters, using a Static Retinal Vessel Analyzer, were completely conducted in 391 children. Measurements of spinal flexibility and spinal posture, using a hand-held computer-assisted electromechanical device, the MediMouse, were performed in 395 children. Additional proxy-reported questionnaires about physical activity behaviour, parental education, household income and nationality were completed by 340 children.

Results

It was found that cardiorespiratory fitness and indoor activity had a positive influence on retinal vessel health. Physically fit children had a more flexible spinal inclination and pelvic tilt than their peers. Boys with a high level of cardiorespiratory fitness had additionally more often a normal spinal posture. Parental education level, household income and migrant background were negatively related to the physical fitness levels and anthropometrics of the schoolchildren. Moreover, children from less educated parents and with a migrant background were spending more time in front of a screen than their peers. By the use of the physical fitness tests 351 (27%) children were recommended for the movement promotion class and 140 (11%) first-graders for the talent promotion program Talent Eye. The remaining 823 (62%) children were recommended for an additional physical sports lesson. Compared to the year before 43 more children registered for movement promotion classes (2012/2013: 11 children, 2013/2014: 54).

Conclusions

In conclusion physical fitness showed a beneficial association with cardiovascular and back health and is related to parental education level, household income and migrant background of first-graders. On the basis of the Sportcheck study the physical fitness level of first-graders of Basel-Stadt could be classified for additional physical education lessons. Besides, more children registered for movement promotion classes. Future follow-ups will analyse whether on the basis of the Sportcheck children will be more active in the long-term.

Chapter 1 **Introduction**

1.1 Children's Physical Activity, Sedentary Behaviour and Physical Fitness

Insufficient physical activity (PA) is causing worldwide 3.2 million deaths each year and is therefore one of the ten leading risk factors for global mortality [1]. Compared to adults reaching the World Health Organization (WHO) PA recommendations of 150 minutes of moderate-to-vigorous PA per week, insufficiently physically active adults have a 20-30% increased risk of all-cause mortality [2]. In this regard it is so much the worse that 23% of adults aged 18 years and older were insufficiently physically active worldwide in 2012. In adolescents, aged 11-17 years, 81% were globally less active than recommended by the WHO, i.e. had less than 60 minutes per day of moderate-to-vigorous PA [2]. In Switzerland 27.5% of the adult population were graded as inactive in 2011, i.e. were less active than 2.5 hours/week with moderate intensity or less than 1.25 hours/week with vigorous intensity [3].

Regular PA is known to play a decisive role in the prevention and treatment of risk factors for cardiovascular diseases and musculoskeletal injuries already in young age [4]. Global PA recommendations for children published by the WHO suggest at least 60 minutes of moderate-to-vigorous PA per day *in addition* to daily life activities [2]. The European Youth Heart study was the first study analysing objectively measured PA in regard to cardiovascular health. It was found that the amount of PA per day should be even 90 minutes with at least moderate intensity to prevent clustering of cardiovascular disease risk factors [5]. Nevertheless, current studies examining whether children meet the PA recommendations are still using the 60 minutes of moderate-to-vigorous PA per day recommendation. An accelerometer-based European study about PA in children, including Switzerland, found that only 4.6% of the girls and 16.8% of the boys met the global PA recommendations [6]. Thereby, the highest percentage of children meeting the recommendations was found in Switzerland. In Switzerland, 12.5% of the girls and 27.8% of the boys are physically active for more than 60 minutes a day [6]. However, this is still a shocking low number, regarding the beneficial health effects of PA such as prevention of developing risk factors for cardiovascular disease or injuries [4, 5].

Besides, it has been shown that time spent sedentary is essential, too. Previous studies found that sedentary behaviour is associated with cardiovascular risk factors from childhood to young adulthood independent from the PA level [7-10]. In a worldwide population of 15 to 59 years old 41.5% spend 4 hours or more per day sitting, in Europe even 64.1% [11].

Swiss children spend on average 8 hours per day sedentary [6]. Despite the clinical relevance of sedentary time, there are still no evidence-based guidelines for sedentary behaviour in youth. Therefore, it has been recommended to research sedentary behaviour in the future to release guidelines targeting children and youth [12]. Based on a review from Tremblay et al. Canada released guidelines advising not to spend more than 2 hours a day in front of a screen and to limit sedentary transportation [13]. But the amount of the duration of sedentary behaviour that increases the risk of chronic diseases remains unclear [12].

Also secular trends of PA are insufficiently documented. Measurements of PA have often been questionnaire-based. This can lead to certain bias, especially when they are proxy-reported. Moreover, intensity and duration of PA is often overestimated in questionnaire-based PA assessments [14]. Objective measurement tools such as accelerometers seem to be more accurate [14]. Therefore, Ekelund et al. discussed in their review that due to methodological issues there is no clear evidence that children's PA levels declined during the last decades [14]. Hence, tracking physical fitness from childhood to adulthood seems to be more accurate compared to assessing physical activity [15]. Reviews about secular trends in physical fitness reported that physical fitness among children is decreasing over time [16, 17]. This trend is seen in aerobic capacity and maximum oxygen intake [16], as well as in power and speed [17]. As reasons for these declines decreased PA, increased sedentary behaviour, increased nutritional status and declined physical education were mentioned [16, 18]. The time trend of the nutritional status is very well documented compared to PA. In this regard, the prevalence of overweight and obesity in children increased worldwide over the last years [19]. In North America 30% of the school age-children are overweight and 15% obese. In Europe the numbers are little lower with 20% overweight school age-children and 5% obese, respectively [19, 20]. However, in Switzerland paediatric overweight and obesity stabilized between 1999 and 2012 [21]. In 2012 14% of the Swiss children between 6 and 12 years were overweight and 3.4% obese, based on the International Obesity Task Force (IOTF) [22]. Against the background that overweight and obesity increase the risk of diabetes type 2, hypertension and hyperlipidaemia already during childhood and adolescence and the risk of cardiovascular disease later in life [23-26], the percentage of overweight and obese children in Switzerland has to be regarded as high.

1.2 Cardiovascular Health

In the year 2012 globally 17.5 million deaths, or 33.4% of all deaths, were caused by cardiovascular diseases and diabetes [27]. In Switzerland cardiovascular disease is the most frequent cause of death and accounts for 29% of total health costs [3, 28]. Therefore, prevention of cardiovascular risk factors is very important. It has been shown that PA and cardiorespiratory fitness are highly important for the prevention and treatment of cardiovascular disease and diabetes in adults, as well as for the prevention of overweight and obesity and cardiovascular risk factors in children and adolescents [4, 24, 27]. Longitudinal studies about PA or cardiorespiratory fitness in childhood and cardiovascular disease in adulthood are scarce. The Amsterdam Growth and Health Longitudinal Study showed that subjects with stiffer arteries had on average a lower VO_2max level and a higher blood pressure during a 24-year period compared to their counterparts with less stiff arteries [29]. It was also found that improving the VO_2max throughout the years by increasing the PA level may contribute to a lower mortality on account of cardiovascular disease, due to decreasing arterial stiffness [30]. Moreover, a Finnish study found that between 13 and 17 years of age a moderate increase in PA correlates with a decelerated progression of the intima media thickness, a marker of subclinical atherosclerosis [31]. In contrast, the European Youth Hearth Study did not find any associations between PA and intima media thickness [32]. An explanation for these different findings could be the difference in age at baseline. While the European Heart study investigated children between eight and ten years at baseline the Finnish study and the Amsterdam Growth study were examining adolescents aged 13 years [29, 31, 32]. Furthermore, measurement protocols of intima media thickness were so far not standardized and since patient preparation and technical equipment deserve special attention, different findings are not unexpected [33]. Besides, in children intima media thickness values have to be compared to age and sex-specific normative data, which are currently in preparation by the Association for European Paediatric Cardiology (AEPC) [33]. A promising new non-invasive method to discover risk factors for cardiovascular disease already in young age at an early stage is the static retinal vessel analysis [34].

1.2.1 Retinal Vessel Analysis and Cardiovascular Disease

Studies in adults have shown that narrower retinal arteriolar diameters and wider retinal venular diameters are associated with a higher risk of obesity [35, 36], hypertension [37, 38], type 2 diabetes [39], stroke [40] and a higher cardiovascular mortality rate [41]. Studies about PA or physical fitness and retinal vessel diameters are scarce, however. An Australian study reported that physical inactivity has a negative influence on the retinal venular diameters in adults [42]. Individuals of the lowest PA quartile were found to have wider retinal venular diameters compared to the highest quartile. Similar results were found in TV time, where adults with more than 3 compared to less than 1 hour of TV time a day had a wider central retinal venular equivalents (CRVE). These associations were not present for the central retinal arteriolar equivalents (CRAE) [42]. A German study found that endurance training improved the arteriolar to venular ratio (AVR) in obese recreational runners as well as in amateur and elite recreational runners [43]. The AVR of the obese runners could even reach normal value post-training. Besides, the study showed that there is a positive association between the individual anaerobic threshold and the AVR. Adults with a higher individual fitness level had a higher AVR and, thus, lower cardiovascular risk [43].

In children there are only few studies analysing retinal vessel diameters. But they show that already in children narrower retinal arteriolar diameters and wider retinal venular diameters are associated with cardiovascular risk factors, such as obesity [44-46], higher blood pressure [47] and higher insulin levels [48]. It seems evident that alterations of retinal vessel diameters occur before common cardiovascular risk factors can be detected [45]. So far two studies analysed PA and retinal vessel diameters in children [48, 49]. A questionnaire-based Australian study found that self-reported PA is associated with wider retinal arteriolar diameters. They also showed that screen time is negatively associated with retinal arteriolar diameters [49]. In contrast, a German study found no associations between PA, physical fitness and retinal vessel diameters [48]. There is a lack of studies analysing PA and physical fitness, especially cardiorespiratory fitness, and retinal vessel diameters in children especially when keeping in mind the promising potential of retinal vessel analysis for early stage cardiovascular risk assessment.

1.3 Back Health

PA and physical fitness have not only a positive influence on cardiovascular diseases but also on back pain [50]. Although back pain is less fatal than cardiovascular disease and therefore often seen as a trivial problem, the costs of low back pain are relatively high [51]. In Switzerland in 2005 the total economic burden of low back pain accounted for 6.1% of the total health costs, and 2.3% of the gross domestic product [52]. This is mainly because in adults low back pain is a very common problem and affects up to 70% of the population [53]. The prevalence of back pain in children is relatively low (1-6%) but increases during adolescence at a very high level of up to 51% [54]. Often low back pain during adolescents leads to future back problems [55]. Therefore, it is important to start with back pain prevention early in life. Thus, certain risk factors for back pain have to be considered. Risk factors for back pain are genetic or constitutional factors, overweight, sex, reduced spinal flexibility, postural insufficiency, reduced fitness or physical inactivity [50, 56-61].

1.3.1 Overweight, Physical Fitness, Physical Activity and Back Pain

A recent meta-analysis about back pain in adults has shown that strength/resistance and coordination/stabilization exercise programs have a beneficial influence on chronic low back pain in adults. In contrast, cardiorespiratory fitness has no influence on back pain [50]. In children there is only a limited number of studies. A recent review reported that exercise interventions targeting low back pain are promising [54]. But, due to a large heterogeneity between the few existing studies, more research data is recommended to strengthen the conclusion. Besides, studies about PA and back pain in school children are rare and show conflicting results [62]. On the one hand it was found that a high level of leisure time PA or a lower level of physical inactivity is associated with a decreased prevalence of back pain [63-65]. On the other hand it was shown that a high level of PA is associated with a higher risk of back pain [66, 67]. These conflicting findings may be due to methodological differences between the studies [62] or because different levels or domains of physical activity may have a different relationship with back pain [61, 68].

1.3.2 Spinal Flexibility and Back Pain

Spinal flexibility, often named spinal or trunk mobility, can be measured in many different ways [69]. Although numerous studies have shown that the error that occurs due to repeated measurements is remarkable, X-ray is considered as gold standard and most frequently used [70-72]. But, in X-ray a relatively high dose of radiation is required [70]. Hence other, non-invasive, external methods, like the radiation free Spinal Mouse, have been developed [70]. The influence of spinal flexibility on back pain has been reported inconsistently. Reduced spinal flexibility has been shown to be a risk factor for back pain in adolescents and adults [57, 58, 73, 74]. Also in back pain patients, the ones with a less mobile spine suffer from more severe back pain [75]. Nevertheless other studies showed no relationship between spinal flexibility and back pain [76, 77]. Here, it has to be considered that different measurement methods are used [69] and that the definition of spinal flexibility is not consistent. While some studies measure the flexibility of the thoracic or the lumbar spine [73, 74, 76, 77], others measure the flexibility of the pelvic tilt or spinal inclination, respectively [57, 58]. In addition, the results are contradictory if either the range of motion [74, 76, 77] was measured or only the flexion and extension of the spine, respectively [57, 58, 73].

1.3.3 Postural Insufficiency and Back Pain

Postural insufficiency is reported to be a risk factor for back pain too [59, 60]. A test to measure postural insufficiency in children is the Matthiass-arm raising test [78]. This test measures whether or not children are capable to control and maintain an upright-standing position for at least 30 seconds with straight arms holding in 90° shoulder flexion. So far, the Matthiass-arm-raising test was conducted mostly subjectively by observation and in many different ways [79-81]. The measurement with a Spinal Mouse offers an easy approach to measure postural insufficiency in an objective way, using the difference of the spinal curvature before and after 30 seconds. Literature on this topic is very scarce. The non-invasive Spinal Mouse promises to be a feasible instrument to measure spinal flexibility and postural insufficiency in a large cohort. Hence longitudinal and intervention studies to examine the association between spinal flexibility, postural insufficiency but also PA and physical fitness and back pain should be performed to figure out if back pain can be prevented in future by for example a flexibility training of the back or by an increased PA.

1.4 Socioeconomic Status and Health

Back pain and cardiovascular disease are also associated with socioeconomic status, which is typically assessed by the factors educational level, occupation and income [27, 82-84]. Braveman et al. suggest to measure the factors of the socioeconomic status as individual factors, because the impact of a single factor and the interaction between the factors on health can vary very much [85]. It has been shown that childhood socioeconomic status can have a negative influence on the development of low back pain in adulthood [82]. Moreover, the WHO reported that a low education level and low income negatively affect cardiovascular health [27]. Therefore, socioeconomic status is associated with the risk factors for both cardiovascular disease and back pain, such as childhood overweight and obesity. A review published in 2005 about studies of the last 15 years reported on an association between childhood adiposity and low socioeconomic status [86]. But a recently published European study showed that the parental socioeconomic status affects childhood overweight or adiposity very differently between countries [87]. While in Belgium, Estonia, Germany, Spain and Sweden the prevalence of pre-schoolers overweight is related to a low socioeconomic status, in Cyprus, Hungry and Italy no association was found. In Switzerland in pre-schoolers there was no association between socioeconomic status and adiposity, but with the children’s physical fitness level. Children of low compared to high educated parents were less agile in an obstacle course [88]. No differences were found in PA. In contrast, a German study found that lower parental socioeconomic status is associated with a lower level of physical fitness and with a less physically active lifestyle of the children [89]. Similarly the European Youth Heart Study found that the prevalence of low cardiorespiratory fitness was higher in children with a low socioeconomic status [90]. Nevertheless, the socioeconomic status did not influence the tracking of physical fitness into adolescence and can therefore not be seen as an indicator for unfit or overweight adults later in life [90]. In contrast, an Australian study found that improvements of the socioeconomic status from childhood to adulthood, indicated by educational level, are related to an increase in PA and cardiorespiratory fitness [15]. They also reported that there was no lasting impact of childhood socioeconomic status on PA in adulthood [15]. In summary, education is important to positively influence both the socioeconomic status from childhood to adulthood and also the PA level and cardiorespiratory fitness. Thus, schools seem to hold a key role also for public health promotion through and beyond their educational mandate. PA interventions at schools have been found to increase the duration of moderate-to-vigorous PA, to increase the VO_2max and to decrease the time spent watching TV of the school children [91]. Hence, sustainable PA programs should be implemented in every school. For this reason the canton Basel-Stadt implemented the Sportcheck in the curriculum of the first-graders in 2014 to assess the children’s physical fitness besides others and to determine PA related deficits in order to implement programs to promote PA and PA related health.

Chapter 2 **Study Aims**

This dissertation aims, as a first phase of the Sportcheck project (detailed information see Chapter 4), to analyse associations between physical fitness and cardiovascular disease risk factors, measured by retinal vessel diameters and blood pressure, and risk factors for back pain, measured by the flexibility of the spine and postural insufficiency in all first-graders of Basel-Stadt. Building on the results of this dissertation back therapy training or adapted physical education lessons are planned to be implemented in the respective schools. In detail, the following aims have been addressed.

Retinal vessel analysis is a new promising method to assess microvascular health non-invasively. Only a few studies examined retinal vessel diameters and anthropometrics in children so far [44-46, 92]. It was found that BMI as well as blood pressure were negatively associated with microvascular health. The available data is still scarce and inconsistent concerning different ethnicities and age-groups. Furthermore, children's blood pressure levels categorizing normotensive, pre-hypertensive and hypertensive have never been associated to retinal vessel diameters before. Therefore, our aim was:

Aim 1: To examine the association between retinal vessel diameters, body mass index, waist circumference, percentage body fat, waist to height ratio and blood pressure categories in young Caucasian children (Chapter 5).

Besides the above mentioned association between anthropometrics and microvascular health, PA has been suggested to have a positive influence on retinal vessel diameters. We therefore investigated whether children's subjectively proxy-reported physical activity behaviour is associated with microvascular health. Furthermore, studies in adults have shown that cardiorespiratory fitness is beneficially associated with the retinal microcirculation. So far there are no studies in children examining this association. Thus, our aim was:

Aim 2: To assess the association of the 20 m shuttle run performance with retinal vessel diameters in young children. Furthermore on an explorative basis, we aimed to examine the association of additional physical fitness parameters with retinal microvascular health. Besides, subjective reporting of physical activity behaviour should be compared to previous findings in young school children (Chapter 6).

Research about back health prevention already during childhood is still very scarce. Not least, because the gold standard method measuring the spine, the X-ray, is expensive and invasive. However, the non-invasive Spinal Mouse promises to be a feasible instrument to measure among others spinal flexibility and postural insufficiency in a large cohort. Hence longitudinal and intervention studies to examine the association between spinal flexibility, postural insufficiency but also anthropometrics, PA and physical fitness and back pain should be performed to investigate whether back pain can be prevented by a flexibility training of the back or by PA promotion. Aiming to provide more information concerning this issue, we started with a cross-sectional study as a baseline examination for upcoming longitudinal analyses.

Aim 3: To analyse the associations between anthropometrics, physical fitness, spinal flexibility and postural insufficiency, as risk factors for back pain, and back pain in 6 to 8 year old children (Chapter 7).

Literature about physical fitness, anthropometrics, PA behaviour and socioeconomic status shows conflicting results. The influence of the socioeconomic status seems to differ between countries and between rural and urban environments. Aiming to improve physical education and physical fitness of all first-graders of the canton Basel-Stadt the association of physical fitness, anthropometrics and socioeconomic status has to be examined in Basel-Stadt.

Aim 4: To examine associations between parental educational level, household income, migrant background and physical fitness, PA behaviour, risk factors for back pain as well as retinal microcirculation in children in an urban Swiss region (Chapter 8).

Chapter 3 **Methods**

3.1 Study Design and Population

The study was designed as a large scale, cross-sectional observational investigation. Participants for the main study were recruited from the Sportcheck project (Chapter 4). Briefly, beginning in 2014 the Sportcheck project includes yearly obligatory assessment of physical fitness of first-graders performed during physical education lessons (approximately 1400 children per year). From the 1314 children participating in the Sportcheck project 2014 1255 completed all physical fitness tests. Moreover, 540 (38.6%) were allowed by their parents to join additional tests on retinal vessel health, blood pressure, spinal flexibility and spinal posture. 200 children dropped out due to illness at one of the two test dates, relocation, incomplete questionnaire, refused to participate in one of the tests or the measurement was rated as invalid. Finally, we had a complete data set of all assessed variables of 340 children, for the retinal microcirculation analyses 391 children and for the back health analyses 395, respectively.

Prior to testing a sample size estimation for every publication was made based on previous findings in similar studies (per publication). Calculated with the software G-Power using a significance level of 5%, a power of 0.9 and a medium estimated effect size a sample size of approximately 210 children in total was calculated to be needed to produce meaningful analyses for the above mentioned dissertation research questions.

3.2 Physical Fitness Tests

The 20 m shuttle run is a validated and reliable (Pearson correlation coefficient r=0.89) test in children aged 6 to 16 years [93, 94] to measure cardiorespiratory fitness by running forth and back for 20 m. The initial running speed is 8.0 km/h with an increase of 0.5 km/h every minute, paced by beeps on a stereo. When the child did not cross the 20 m line at the moment of the beep for two consecutive 20 m distances the maximal performance was reached. With a precision of 0.5 stages numbers of "stages" (1 stage≅1 minute) performed were counted [95]. To measure speed (or explosive strength) a 20 m sprint was conducted. The test has been shown to be reliable in 6 to 11 year old children (r=0.9) [96]. Times were assessed by electronic timing gates (HL2-31, Tag Heuer, La Chaux-de-Fonds, Switzerland), starting from an upright position. The start followed after an acoustic signal, with a precision of 1/100 second. This test had to be performed twice and as fast as possible. The faster trial was further analysed. Speed and coordination were measured with the jumping sidewards test [97]. The test was found to be reliable in children aged 5 to 14 years (Intra-class correlation coefficient (ICC)=0.95) [98]. In this test children repetitively jumped, within 15 seconds, on alternating sides of a wooden strip, as many times as possible. During jumping, both legs had to be kept together. This task had to be performed two times as fast as possible. The sum of the two trials was included in further analysis. Children were allowed to perform five single test jumps prior to testing. The balancing backwards test was conducted to measure coordination. The test includes balancing backwards on 3 m long bars with a width of 3, 4.5 and 6 cm, respectively. In children aged 5 to 14 years the test was found to be reliable (ICC=0.8) [97, 98]. Starting with the 6 cm and ending with the 3.5 cm bar, 3 trials were performed for each bar width. Children were allowed to balance once forward and once backwards over the widest bar prior to testing. The number of steps until the child's foot touched the floor was counted. For statistical analysis the sum of these 9 trials was used.

3.3 Anthropometry

Body height was measured with a wall-mounted stadiometer to the nearest 0.2 cm without shoes (Seca 206, Seca, Basel, Switzerland). Body weight was examined without shoes in light clothing to the nearest 50 g using an electronic scale (Seca 899, Seca, Basel, Switzerland). Thereof BMI was calculated by dividing body weight by height in meters squared. Children were classified as either non-overweight, overweight or obese based on the International Obesity Taskforce (IOTF) reference for children [22]. Waist circumference was measured using a flexible tape at the natural waist (half way between the ribcage and the iliac crest). Skinfold thickness was measured with Harpenden calipers (HSK-BI, British Indicators, Burgess Hill, United Kingdom) in triplicate to the nearest 0.5 mm. Calibrated to exert a pressure of 10 g/cm^2 at two sites (triceps and subscapular) based on standard procedures. The two skinfolds were taken to calculate percent body fat [99]. Systolic and diastolic blood pressure (mmHg) was measured after a rest period of five minutes at the bare right arm based on the recommendations of the American Heart Association [100]. Children were seated in a comfortable position in a quiet room. In order to reduce inter-observer variability, an automated oscillograph (Oscillomate, CAS Medical Systems, Branford, CT, USA) was used. Blood pressure measurements were taken five times. The mean of the three measurements with the smallest variation was used for further analysis [101].

3.4 Static Retinal Vessel Analyzer

The Static Retinal Vessel Analyzer (SVA-T, Imedos Systems UG, Jena, Germany) is an ophthalmoscopic instrument capable to measure the retinal vessel diameters non-invasively and non-mydriatically. The Static Retinal Vessel Analyzer package integrates a fundus camera (Topcon TRC NW8) with a software-guided image processing unit (Visualis, Imedos Systems UG) [102]. Two images of both eyes were taken from the retina, with the optic disc in the centre and an angle of 30° [103]. Retinal vessel analysis was performed by a single experienced examiner by using special developed analysing software identifying retinal vessels in ring-zones (Vesselmap2, Imedos Systems UG). After assigning the papilla in the image, the examiner identified all retinal arterioles and venules in the outer ring zone (0.5-1 disc diameter from the margin of the optic disc) semi-automatically (Figure 1).

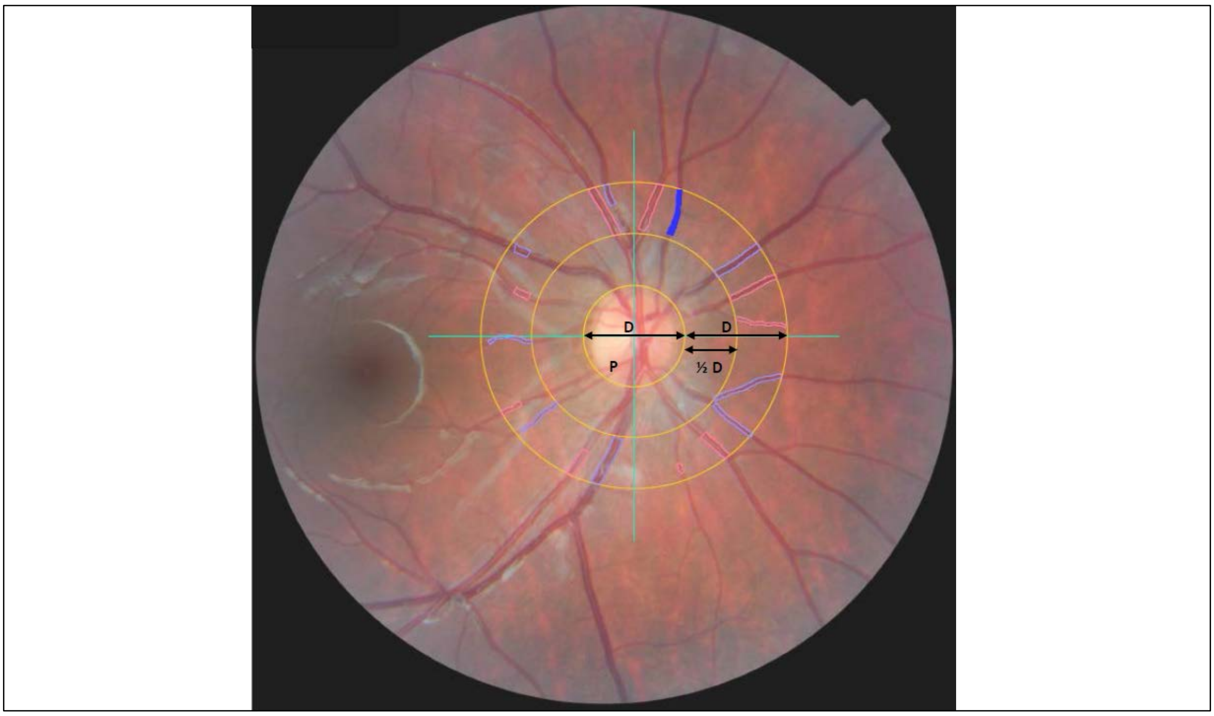

Figure 1. Image of a retina analysed with static retinal vessel analysis: blue and red lines in the outer ring zone identify retinal vessels; diameter of the papilla (P) and the optic disc (D).

The diameters were measured by the automated software in CRAE and CRVE using the Parr-Hubbard formula [102]. The AVR was calculated using the CRAE and CRVE. Diameters were presented in measuring units (mu). According to Gullstrand's model of the normal eye, 1 mu related to 1 µm. Vessel diameters bellow 0.42 mu were generally ignored. The assessments of the retinal vessels were performed early in the morning in a fasting state.

3.5 Spinal Mouse

Spinal flexibility and spinal posture were measured with the Spinal Mouse MediMouse® (Idiag, Fehraltorf, Switzerland), a hand-held computer-assisted electromechanical device. The device was guided slightly paravertebral of the spine or along the midline in overweight and obese children, respectively. Starting at the spinous process of the vertebrae prominens (C7) and finishing at the top of the anal crease (approximately S3). The landmarks were initially identified by palpation and marked on the skin with a cosmetic pencil. Two rolling wheels followed the contour of the spine. Distance and angle measures were noted. Data was sampled every 1.3 mm as the mouse was rolled along the spine. The sampling frequency was approximately 150 Hz [72]. Spinal curvature can be measured in flexion and extension [72]. In every position three sets of measurements were taken. The mean of the two measurements with the smallest variation was used for further analysis. Afterwards the range of motion between the spinal curvature in flexion and in extension was calculated as the measure of spinal flexibility. An exclusive function of the Spinal Mouse is that it measures the spinal flexibility of the thoracic, lumbar and pelvic tilt separately. The forth flexibility parameter, the spinal inclination, is described as the angle subtended between the vertical axis between legs and pelvis and a line joining C7 to the Os sacrum (Figure 2) [70]. This Spinal Mouse was found to be reliable in adults (ICC>0.85) and in children (ICC>0.87) [70, 104].

The Matthiass-arm-raising test was conducted [105] to assess the capability of the children to control and maintain an upright-standing position for at least 30 seconds with straight arms holding in 90° shoulder flexion. The difference between the spinal curvature before the 30 seconds and after was calculated for the Os sacrum, the lumbar spine and the spinal inclination. Postural insufficiency was defined as follows: A) extensive shift of the Os sacrum in the ventral direction, B) increase of the lumbar lordosis or C) an extensively decreased spinal inclination [106] (Figure 2).

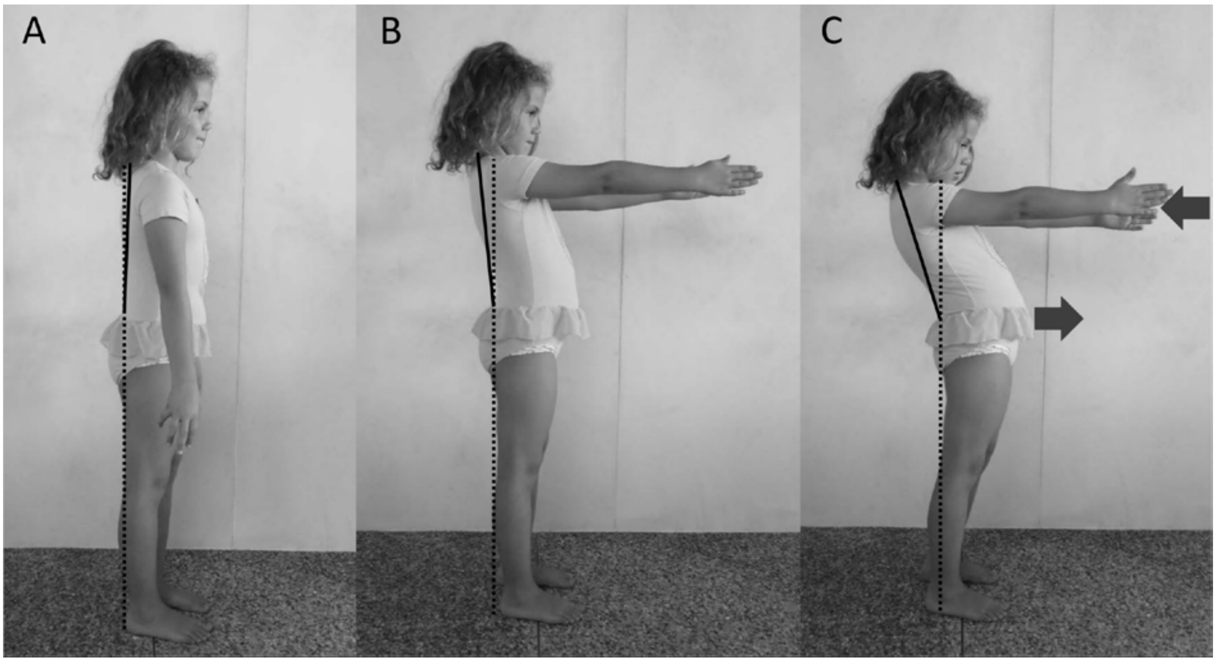

Figure 2. Matthiass-arm-raising-test. (A) The vertical axis between legs and pelvis (dotted line) and the spinal inclination (solid line) standing upright, (B) after 30 seconds with straight arms holding in 90° shoulder flexion graded as normal posture, and (C) graded as postural insufficiency. In C the exemplary postural insufficient child shows an extensive shift of the pelvis in ventral direction and an extensive decreased angle of the inclination (arrows).

3.6 Questionnaire

To assess the children's PA behaviour parents were asked to fill out an interview-based questionnaire about their children's PA, screen time and back pain. In addition, parents were asked to complete a questionnaire to assess parental educational level, household income and nationality. The questionnaire was previously developed and established in Switzerland [107]. Questions included PA (time spent in vigorous activity (min/day)), time playing indoor (min/day) and outdoor (min/day), sports club participation (how many times a week and time (in min) participating in a sports club per week) and screen time (time spent watching TV, playing video games and playing on a smartphone (min/day). Answers to parental educational level, household income and nationality were analysed as followed. Parental educational level was determined in terms of the highest school level completed. Low educational level was defined as only one parent with a vocational training, but no tertiary education. High educational level was defined as both parents having a tertiary education. Tertiles of monthly income per household were taken as levels of household income. Low household income was defined as under CHF 5000.-/month, the highest level as over CHF 9000.-/month. Parental migrant background was determined by their country of birth.

Families were classified as migrants in case both parents were from Eastern or Southern European countries, Africa, Asia, Central or South America, or less developed countries [108]. Back pain of the children was assessed with a pain questionnaire [109]. When back pain was reported, the frequency was asked.

Chapter 4 **Sportcheck**

The Sportcheck is a project in cooperation between the Department of Sports, Exercise and Health of the University of Basel, the Department of Education of Basel-Stadt and the Cantonal Office of Sport of Basel-Stadt. The participants for the dissertation were recruited from the Sportcheck. The Sportcheck includes physical fitness tests performed during obligatory physical education lessons at all public schools in the Swiss canton Basel-Stadt (approximately 1400 children per year). For a deeper understanding of the dissertation and to show the direct impact of the Sportcheck on public health, an overview of the aims, design and results are given in this chapter.

4.1 Aims

The Sportcheck aimed at:

1) a continuous monitoring of the physical fitness development and anthropometry of all first-graders of the canton Basel-Stadt. Beginning in 2014, the Sportcheck takes place every year in spring. Annually an overweight/obesity map and a map of physical fitness of the children of every school will be drawn. When children at one school show a consisting low level of physical the Cantonal office of Sport of Basel-Stadt will support the schools to improve the fitness on the children with either further education for the teachers or with additional physical education lessons developed for the specific children’s needs of the respective school. For example a dancing lesson for girls with a migrant background, depending on an analysis of requirements.

2) improving the classifications for the additional physical education lessons, offered in every school. In addition, it is an aim of the Sportcheck to motivate more children to participate in the additional physical education lesson. All parents and teachers of the children received fitness recommendations and a personalized invitation to one of these additional physical education lessons based on the results they achieved in the Sportcheck (Appendix A). In Basel-Stadt children have three options for additional physical education as explained in the following paragraphs: movement promotion, additional sports lesson and Talent Eye.

4.1.1 Movement Promotion

The movement promotion classes are for children with impaired motor skills and a high percentage of these children are in addition overweight or obese. The aim of this class is to motivate also these children to engage in PA and to improve their motor skills in a protected environment. Every class consists of small numbers of children. Therefore, the teacher has enough time to teach individually. Every child should experience the feeling of success.

4.1.2 Additional Sports Lesson

The additional sports lesson is open for all children. Different classes, like swimming, dancing, ball games, etc. are offered. The aim is to reach as many children as possible to be active additional 60 minutes a week.

4.1.3 Talent Eye

Talent Eye is a program for very talented children. The aim of the project is to promote talented children as early as possible and to create the best possible conditions for a possible future career as an athlete. Every year the best 48 first-grade children of Basel-Stadt were recruited in a separate fitness test. Those tests include the same tests as the Sportcheck and additionally a tapping test, sit ups, standing broad jump and target throwing. The program takes two years and consists of two half day sessions a week of physical education taught by a physical education teacher.

4.2 Methods

The Department of Education of Basel-Stadt required that the Sportcheck tests should not last more than 60 minutes per class. The Sportcheck therefore consisted of measurements of body weight and height, a 20 m shuttle run, a 20 m sprint, jumping sidewards, balancing backwards (detailed information see Chapter 3). Prior to testing a standardized 5 minute warm-up was performed.

4.2.1 Overweight/Obesity and Physical Fitness Maps

To map the overweight/obesity status and the physical fitness of the children of the canton Basel-Stadt the geographic information system ArcMap 10.2.1 (Esri ArcGIS) was used. Percentage of overweight/obese children were calculated according to IOTF cutoffs [22]. Z-scores (difference of individual change minus overall mean change score/overall SD of change score) for every physical fitness test were stratified by age and sex [110]. To provide an overall estimate of physical fitness a summary score as the average of z-scores of the four physical fitness tests was calculated [110]. Afterwards the overweight z-scores, physical fitness respectively, of every school were calculated by the mean of the individual z-scores of every child. Z-scores were divided in quintiles to categorize the level of overweight/obesity, physical fitness respectively, in the Sportcheck cohort. The calculated z-scores were linked with the catchment area of the schools as a basis for the drawing of the maps.

4.3 Results

After the first execution of the Sportcheck the following results can be presented. 26 schools and 76 classes were involved, 1314 children took part in the Sportcheck. 637 (48%) were girls and 677 (52%) boys. Mean age was 7.4 years (standard deviation (SD) 0.4). 12.2% of the children were overweight and 5.9% obese. More girls were overweight or obese than boys. Table 1 shows baseline characteristics separated by sex. Boys were better in the 20 m shuttle run (p<0.01), 20 m sprint (p<0.01), and jumping sidewards (p=0.01), whereas girls performed better in balancing backwards (p<0.01).

Table 1. Baseline characteristics of the Sportcheck population separated by sex.

Parameter	Female (N=637)		Male (N=677)		p-value	Cohen's d
	Mean	SD	Mean	SD		
Age	7.4	0.4	7.5	0.4	0.09	0.09
Height (cm)	125.7	5.6	127.1	5.7	<0.01	0.3
Weight (kg)	26.6	2.5	26.8	5.4	0.1	0.09
BMI (kg/m^2)	16.6	2.5	16.5	2.6	0.5	0.04
Overweight (in %)	14.3		10.2			
Obese (in %)	6.1		5.8			
20 m Shuttle Run (stage)	3.7	1.4	4.5	1.7	<0.01	0.5
20 m Sprint (s)	5.04	0.39	4.89	0.40	<0.01	0.4
Jumping sidewards (sum of jump counts)	44.6	11.4	46.3	11.9	0.01	0.2
Balancing backwards (sum of steps)	40.1	12.6	34.4	12.4	<0.01	0.5

4.3.1 Overweight/Obesity and Physical Fitness Maps

In the year 2013/2014 the following maps were generated to display the overweight/ obesity and physical fitness distribution of children participating in the Sportcheck project conducted in Basel-Stadt (Figure 3 & Figure 4)

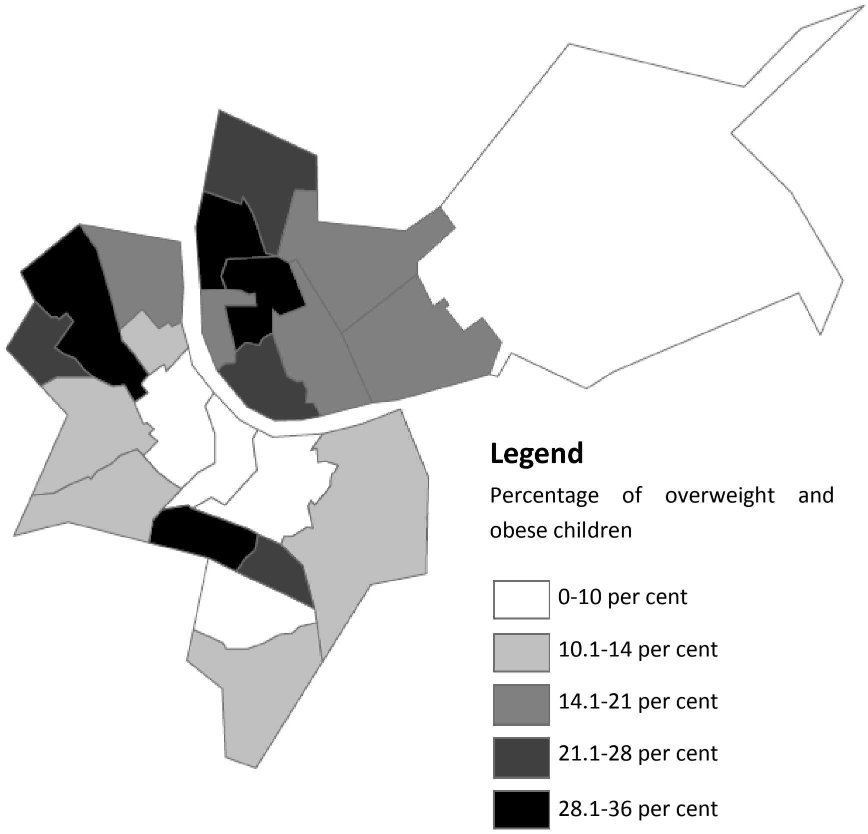

Figure 3. Overweight/obesity map of Sportcheck participants conducted in Basel-Stadt by school (N=1314) (2013/2014).

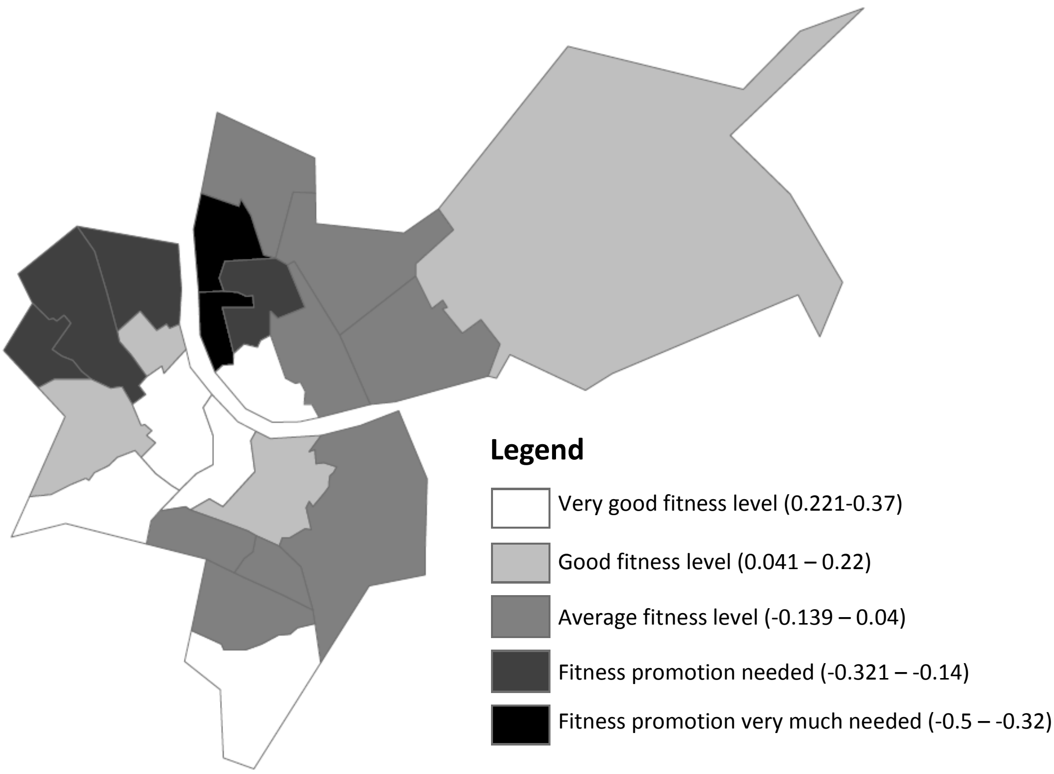

Figure 4. Physical fitness map of Sportcheck participants conducted in Basel-Stadt (N=1314) (2013/2014).

It needs to be mentioned that after only one year of data collection the maps should not be over-interpreted. We did not statistically analyse the differences between the schools yet, because the sample size per school is too small for cluster analysis. But, it is intended to draw the maps for the Sportcheck cohort every year and track similarities or disparities in overweight/obesity and physical fitness by schools of Basel-Stadt.

4.3.2 Registration for Movement Promotion Class

A recently published review and meta-analysis examined whether the type of intervention matters for combating childhood obesity [111]. It was shown that organised sport has the biggest impact on obesity. Thanks to the Sportcheck we could increase the registrations for the movement promotion class. 351 (27%) children received a recommendation for movement promotion. Thereof 54 (15.4%) children participated in the movement promotion class compared to 11 children in the year before. Compared to the year before when only 11 children took part in the movement promotion class this is an increase of 390%.

4.3.3 Registration for Additional Sports Lesson

Of all first-graders (1314) 301 children (22.9%) registered for the additional sports lesson in the year 2014/2015. Compared to the year before when 24.6% of the first-graders registered, the registration rate decreased. But in the year 2014/2015 over all registrations for additional sports lessons (first- to sixth-graders) the percentage of registrations of first-graders increased about 30% compared to the year before.

4.3.4 Registration for Talent Eye Fitness Test

140 children (11%) were recommended to participate at the Talent Eye fitness test. Thereof 37 children (26%) registered for the test. Of those 37 only three children (8%) were not selected for Talent Eye. Therefore, the Cantonal office of Sport of Basel-Stadt decided to replace the separate Talent Eye testing by the Sportcheck. Hence in the year 2015/2016 the children for the Talent Eye project will be selected based on the Sportcheck tests.

4.3.5 Teachers Profit

All teachers received a feedback of the physical fitness performance for every child of their class. Every test performance of every child was graded in five levels (Fitness promotion very much needed, fitness promotion needed, average fitness level, good fitness level and very good fitness level) (Appendix B). In addition, teachers were informed if the children were overweight or obese and what kind of recommendation for the additional sport lesson they got (movement promotion, sports lesson or Talent Eye). In a first step a booklet was developed by the Cantonal Office of Sport of Basel-Stadt to guide teachers how to improve the specific fitness parameters measured in the Sportcheck (Appendix C).

Chapter 5 **Publication 1**

Association of body composition and blood pressure categories with retinal vessel diameters in primary school children

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Lukas Zahner

Arno Schmidt-Trucksäss

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Hypertension Research (2016), 1–7

www.nature.com/hr

ORIGINAL ARTICLE

Association of body composition and blood pressure categories with retinal vessel diameters in primary school children

Katharina Imhof, Lukas Zahner, Arno Schmidt-Trucksäss and Henner Hanssen

Alterations in retinal vessel diameters have been shown to be predictive of cardiovascular risk in adults and children. The aim of our study was to examine the association of body composition and blood pressure (BP) categories with retinal vessel diameters in school children. We examined anthropometric parameters, BP and retinal arteriolar (CRAE) and venular (CRVE) diameters as well as the arteriolar-to-venular diameter ratio (AVR) in 391 children (age: 7.3, s.d. 0.4). Differences between the lowest and highest BP quartiles indicated that higher systolic and diastolic BP were associated with narrower CRAE ($P<0.001$ for both). Children in the highest weight quartile had narrower CRAE compared with the lowest quartile ($P=0.05$). In the regression analysis, systolic and diastolic BP were associated with arteriolar narrowing (–0.4 measuring units (mu) per mm Hg, 95% confidence interval: [−0.6; −0.3] and −0.6 mu per mm Hg [−0.7; −0.4], respectively; $P<0.001$ for both). An independent association was found for diastolic BP only. Compared with normotensives (NT; 74.4% of cohort), arteriolar narrowing was already seen in children categorized as pre-hypertensive (PHT) (11.5% of cohort), which was similar to HT children (14.1% of cohort) (NT: mean 207.2 [205.6; 208.7] mu; PHT: 201.7 [197.8; 205.7] mu; HT: 199.7 [196.2; 203.3] mu; $P=0.01$ for PHT *vs.* NT and $P<0.001$ for HT *vs.* NT in systolic BP). Our results suggest that systolic and diastolic BP are main determinants of retinal arteriolar diameters; and therefore, microvascular health in young children. Pre-hypertension seems to be associated with retinal microvascular alterations early in life.
Hypertension Research advance online publication, 14 January 2016; doi:10.1038/hr.2015.159

Keywords: anthropometry; microcirculation; pre-hypertension; retinal vessels; youth

INTRODUCTION

It has been shown that alterations in retinal vessel diameters are related to a higher risk of obesity[1] and hypertension,[2] an increased risk of stroke[3] and a higher cardiovascular mortality rate in adults.[4] A graded association of narrower retinal arterioles with increasing blood pressure (BP) has been shown.[5–7] In children, a handful of studies on the association of retinal vessel diameters with body composition and BP have been conducted. Greater body mass index (BMI) has been found to correlate with narrower retinal arterial diameters, wider retinal venular diameters and a lower arteriolar-to-venular ratio (AVR).[8–11] Height, weight and waist circumference also seem to influence retinal vessel diameters in children.[8,11] Most of these studies have examined the association of either body composition or BP with retinal vessel diameters in an Asian or mixed race population. A study in an Australian and Singapore cohort of primary school children found an association of higher systolic and diastolic BP with retinal arteriolar narrowing.[12] In preschool-aged children as young as 3–6 years, BMI and systolic BP had an inverse association with retinal arterioles and BMI was positively associated with retinal venular diameters.[13] In a recently published large-scale survey in the Netherlands examining 4000 school children with a median age of 6, higher systolic as well as diastolic BP were associated with retinal arteriolar narrowing.[14] A German study in 10- to 12-year-old school children reported an association between retinal vessel alterations, BP as well as BMI.[11] Higher BMI was associated with wider venular diameters and systolic BP with arteriolar narrowing. In a recent survey of over 700 children and adolescents in China, the Guangzhou Twin Eye Study, body composition was only found to be associated with retinal vessel diameters in older children and adolescents aged 12–19 years and not in younger children.[15] Therefore, the available data are scarce and seem inconsistent, with findings depending on age-group and ethnic population. Retinal arteriolar narrowing has been shown to be associated with large artery stiffness, an indicator of (pre-)atherosclerosis in the macrocirculation.[16] Other potential markers of preterm atherosclerosis include fetal aortic wall thickness, which has been shown to be a very early marker of hypertension.[17]

Few studies have analyzed the association of body composition and BP in a single study to compare their impact on retinal microvascular health in the same population. In addition, waist-to-height ratio is more strongly associated with cardiovascular risk factors than the BMI

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in children and has not yet been related to retinal microvascular health.[18–23] Moreover, BP levels categorizing normotensive (NT), pre-hypertensive (PHT) and hypertensive (HT) children have not been associated with retinal vessel diameters before. In our sample of healthy primary school children, we therefore aimed to investigate the association of retinal vessel diameters with BMI, waist circumference, percentage body fat, waist-to-height ratio and BP categories in 6- to 8-year-old primary school children.

METHODS

Study design and participants

The study was designed as a large-scale, cross-sectional study. In 2014, the Sportcheck study investigated all first-grade pupils of primary schools in the canton Basel-Stadt. From the 1255 children that took part in measurements of weight and height, 540 (43%) were allowed by their parents to join additional tests on anthropometric parameters, BP and static retinal vessel diameters. Due to illness at one of the two test dates or relocation, 149 children dropped out. From the full cohort, 391 children took part in the anthropometric and retinal microvascular measurements (Figure 1). The study was approved by the ethics committee of the University of Basel (EKBB, Basel, No. 258/12). Written informed consent was obtained from all study participants and their families.

Static retinal vessel analysis

Measurements of retinal vessel diameters were performed using a Static Retinal Vessel Analyzer (SVA-T, Imedos Systems UG, Jena, Germany). The system allows non-invasive and non-mydriatic measurements of retinal vessel diameters. It consists of a Topcon fundus camera and an advanced image processing unit (Vesselmap 2, Visualis, Imedos Systems UG).[5] The method and procedures have been described in detail elsewhere.[11] Briefly, four valid digital images were taken from the retina of the left and the right eye, with an angle of 30° and the optic disc in the center.[24] Using the Parr-Hubbard formula, diameters were calculated to central retinal arteriolar (CRAE) and venular (CRVE) equivalents.[5] The AVR was calculated using CRAE and CRVE. Retinal vessel diameters are presented in measuring units (mu). One measuring unit relates to 1 μm in the model of Gullstrand's normal eye. The assessment of the retinal vessels was performed by a single experienced examiner. Reproducibility for all three parameters was high with a correlation coefficient for CRAE of $r=0.94$ and a coefficient of variation (CV) of 2.1%. For CRVE, the correlation coefficient was $r=0.95$ and the CV was 2.0% (AVR: $r=0.94$ and CV = 2.3%) ($P<0.001$ each).

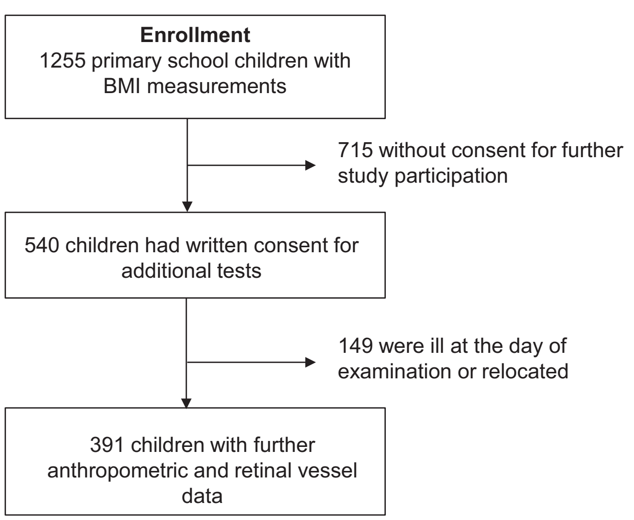

Figure 1 Study flow diagram.

Body composition and BP

Body height was measured without shoes to the nearest 0.2 cm using a wall-mounted stadiometer (Seca 206, Seca, Basel, Switzerland). Body weight was determined in light clothing and without shoes to the nearest 50 g using an electronic scale (Seca 899, Seca). BMI was calculated by dividing body weight by height in meters squared. Waist circumference was measured using a flexible tape at the natural waist (half way between the ribcage and the iliac crest). Skinfold thickness was measured in triplicate to the nearest 0.5 mm with Harpenden Calipers (HSK-BI, British Indicators, West Sussex, UK), calibrated to exert a pressure of 10 g cm^{-2} at two sites (triceps and subscapular) based on standard procedures.[25] The two skinfolds were taken to calculate percent body fat. The waist-to-height ratio was calculated by dividing the waist circumference by height (in cm).[20]

On the basis of the recommendations of the American Heart Association, BP (mm Hg) was measured after a rest period of 5 min at the bare right arm.[26] Children were seated in a comfortable position in a quiet room. To reduce inter-observer variability, an automated oszillograph (Oscillomate, CAS Medical Systems, Branford, CT, USA) was used. The standard cuff-size for children of 12–19 cm fitted all children. BP measurements were taken five times. The mean of the three measurements with the smallest variation was used for further analysis.[27] Systolic and diastolic BP were categorized in NT, PHT and HT based on the reference values by age, sex and height measured in the German Health Interview and Examination Survey for Children and Adolescents (KiGGS 2003–2006), including a large German cohort of over 17 500 children aged 3–17 years.[28] According to the reference of this large German cohort, children were classified as PHT with a BP over the 90th percentile and as HT with a BP over the 95th percentile, which is considered as a widespread convention.[27–29] The KiGGS BP reference values are not influenced by the prevalence of overweight children in the reference population and they are based on validated oscillometric devices.

Statistical analysis

Sample size was estimated based on previous findings in BP and retinal vessels in children.[11] On the basis of this study, the estimated effect size (Cohen's *d*) was considered as moderate ($d=0.6$). Calculated with the software G-Power using F-tests ($f=0.25$, power = 0.90 and 5% level of significance), we estimated the sample size to be approximately 290 children in total. To describe baseline characteristics, descriptive statistics were performed. Mean (95% CI) CRAE, CRVE and AVR were compared across anthropometric parameters' 1st and 4th quartiles by use of univariate analysis of covariance with age and sex as a covariate, and BP was additionally adjusted for BMI. BMI was also analyzed as *z* scores calculated for sex and age. To analyze retinal vessel diameters in different categories of systolic and diastolic BP, univariate analysis of variance was performed. To estimate absolute changes in retinal arteriolar and venular diameters for one unit change of anthropometric parameters, multiple linear regression analysis was applied. Pearson's correlation coefficient and coefficient of variation were estimated to evaluate the reproducibility of retinal photographs. We used Stata version 12.1 (StataCorp LP, College Station, TX, USA) for our analyses. 95% confidence intervals were presented for measures of effect to indicate the amount of uncertainty.

RESULTS

Baseline characteristics of the study population with and without retinal photographs are shown in Table 1. BP values for all children with retinal images according to age, sex and height are shown in Table 2. Comparing the 1st with the 4th quartile of children's BMI, a tendency for wider retinal arterioles in children with lower BMI was found (3.9 mu, $P=0.06$). Looking at the interquartile differences, taller children had narrower retinal arterioles (−4.7 mu, $P=0.03$) and a lower AVR (−0.02; $P=0.02$). Likewise, heavier children showed narrower arterioles (−4.8 mu, $P=0.05$) and a lower AVR (−0.02, $P=0.05$). However, after adjusting for BP, no significant differences were found for any parameter of body composition (data not shown). No differences were found between waist-to-height ratio and the interquartiles of retinal vessel parameters ($0.3<P<0.7$). On

Table 1 Baseline characteristics of the study population

	Children with gradable retinal photographs			Children without gradable retinal photographs		
Parameter	N	*Mean*	*s.d.*	N	*Mean*	*s.d.*
Age	391	7.3	0.4	864	7.5	0.4
Sex						
Female	200			389		
Male	191			475		
Height (cm)	391	126.3	5.3	862	126.7	5.8
Weight (kg)	391	26.1	4.5	862	26.9	5.6
BMI (kg m^{-2})	391	16.3	2.1	862	16.6	2.6
Waist circumference (in cm)	391	58.1	6.0			
Percentage body fat (%)	391	16.8	5.0			
Waist-to-height ratio	391	0.46	0.04			
Systolic blood pressure (mm Hg)	391	104.7	7.9			
Diastolic blood pressure (mm Hg)	391	65.7	6.7			
CRAE (mu)	391	205.5	13.7			
CRVE (mu)	391	231.6	13.6			
AVR	391	0.89	0.05			

Abbreviations: AVR, arteriolar-to-venular ratio; BMI, body mass index; CRAE, central retinal arteriolar equivalent; CRVE, central retinal venular equivalent.

the basis of interquartile differences between the lowest and the highest BP quartiles, higher systolic BP was associated with arteriolar narrowing (−9.0 mu, $P<0.001$) and a smaller AVR (−0.03, $P<0.001$). Higher diastolic BP correlated with narrower retinal arterioles (−10.1 mu, $P<0.001$), narrower venules (−3.5 mu, $P=0.05$) and a smaller AVR (−0.03, $P<0.001$) across the quartiles (Table 3).

In the regression analysis, CRAE correlated negatively with height and weight but failed to do so after adjustment for systolic and diastolic BP (Table 3). For every mm Hg increase in systolic BP, CRAE decreased by 0.4 mu ($P<0.001$) and AVR decreased by 0.001 ($P<0.001$). However, the association was dependent on diastolic BP. Associations of diastolic BP with retinal arteriolar narrowing were independent of age, sex, BMI and systolic BP. For every mm Hg increase in diastolic BP, CRAE decreased by 0.4 mu ($P=0.003$) after adjustment for confounders (Table 4).

In our cohort, 74.4% of children were categorized as NT ($n=291$), 11.5% as PHT ($n=45$) and 14.1% ($n=55$) as being HT on the basis of systolic BP levels according to the above KiGGS criteria.[28] Children with systolic PHT had narrower retinal arterioles compared with children with NT (−5.5 mu, $P=0.01$), which was similar to findings in children with HT (−7.5 mu, $P<0.001$). Similar results were found for diastolic BP categories and CRAE (Table 5). No differences between the BP categories were found for CRVE. Children in the systolic (−0.02, $P<0.001$) and the diastolic HT category showed a lower AVR compared with NT (−0.03, $P<0.001$). No differences between the NT and PHT categories were found for AVR (Table 5).

DISCUSSION

Our results demonstrate that BP is associated with retinal microvascular alterations in children aged 6–8 years of age. In children with PHT, categorized according to one of the largest childhood surveys in Europe (KiGGS 2003–2006), retinal arteriolar narrowing can already be detected. In adults, high normal BP seems to be linked with a lower AVR and retinal arteriolar narrowing.[30] This is the first study demonstrating the adverse effects of PHT on retinal microvascular health in children as young as 6–8 years. In adults, arteriolar narrowing is associated with incidence of hypertension and risk of coronary artery disease, and it predicts cardiovascular morbidity and mortality.[2,4,31,32] Therefore, retinal arteriolar narrowing is a preclinical marker of cardiovascular risk and disease manifestation in adults. Whether retinal arteriolar narrowing in young children represents adverse microvascular impairments and predicts future cardiovascular risk remains to be investigated. However, previous studies have shown that childhood BP is associated with future hypertension and cardiovascular mortality.[33,34] A recent Chinese study found that children aged 6 with elevated BP have accelerated cardiac remodelling and vascular dysfunction in adulthood.[35] In our study, retinal arteriolar narrowing is associated with higher systolic and diastolic BP but only diastolic BP was independently associated with retinal arteriolar narrowing. This indicates the importance of diastolic BP as a determinant of microvascular health in children. Previous studies in adults have shown that both systolic and diastolic BP are primarily associated with retinal arteriolar narrowing. Our findings in children are in line with the available data. The autoregulation of the retinal vascular bed ensures that retinal perfusion remains the same over a wide range of BP increases. To normalize retinal perfusion pressure when exposed to higher BP, retinal arteries contract (myogenic response) and, therefore, protect the sensitive capillary bed behind it from increased pressures. Longer term, the vascular wall of retinal arterioles thickens and the lumen diameter decreases (remodelling) leading to arteriolar narrowing. We also found correlations of body composition with retinal vessel diameters in our cohort. Although our findings for BMI and retinal vessel diameters are similar to previous findings, our associations of BMI with retinal vessel diameters were not independent of BP. In a recent Chinese study, associations of body composition and retinal vessels were only found in older children (12–19 years) and not in younger children (7–11 years).[15] In a previous study in pre-adolescent children, BMI was adjusted for mean arterial pressure and was independently associated with narrower arterioles and wider venules.[10] Our study was the first to analyze the association of waist-to-height ratio, as a marker of central obesity, and retinal microcirculation. We found no relationship between the waist-to-height ratio and retinal vessel diameters. Compared with BMI measurements, the waist-to-height ratio is independent of age and includes the fat mass of the body.[18]

Our findings are of high clinical relevance for cardiovascular health promotion in school children. Our results demonstrate that BP and, to a lesser extent, body composition are main determinants of retinal microvascular health in young children. Body composition and BP are often interdependent in adulthood and childhood. Most strikingly, PHT in healthy children is already associated with retinal arteriolar narrowing. This may prove to be indicative of an increased future cardiovascular risk in young children with PHT. In our study, about 25% of children were found to be either PHT or HT. Similar adverse associations with retinal vessel diameters were seen in both BP categories. These children are likely to benefit most from future school and family-based lifestyle intervention strategies.

Our results go in line with the results of the previous German study, which used the same equipment, software and analyzing routine for retinal vessel analysis.[11] Compared with the German cohort, the mean CRAE was 3 mu and the mean CRVE 5 mu smaller in our cohort. This is likely because of the age difference with a mean age of 7.3 years (SD: 0.4) in our study and a mean age of 11.1 years (SD: 0.6) in the German cohort. The sex differences are also similar to the German study. Girls are more likely to have wider retinal arteriolar and venular

Table 2 Mean blood pressure of our cohort by gender, age and height classified in blood pressure categories according to the KiGGS study (2003–2006)

			Systolic blood pressure						*Diastolic blood pressure*					
			Normotensive		*Pre-hypertensive*		*Hypertensive*		*Normotensive*		*Pre-hypertensive*		*Hypertensive*	
Sex	*Age (years)*	*Height (cm)*	N	*Mean mm Hg (s.d.)*	N	*Mean mm Hg (s.d.)*	N	*Mean mm Hg (s.d.)*	N	*Mean mm Hg (s.d.)*	N	*Mean mm Hg (s.d.)*	N	*Mean mm Hg (s.d.)*
Male	6	113	1	94.6 (—)	0	—	0	—	1	54.0 (—)	0	—	0	—
		115	3	102.3 (3.9)	0	—	0	—	3	60.7 (1.9)	0	—	0	
		118	3	96.7 (4.1)	0	—	0	—	3	58.4 (4.9)	0	—	0	
		121	8	103.0 (3.5)	2	109.2 (0.2)	1	111.3 (—)	8	61.3 (4.9)	2	69.5 (0.7)	1	71.0 (—)
		125	4	105.3 (1.9)	2	110.0 (1.4)	0	—	3	66.0 (1.8)	0	—	3	79.9 (1.3)
		128	4	95.7 (8.1)	1	111.7 (—)	1	118.7 (—)	6	61.6 (8.0)	0	—	0	—
		130	4	104.8 (3.4)	0	—	0	—	4	58.3 (6.3)	0	—	0	—
	7	116	4	101.3 (3.1)	1	108.0 (—)	0	—	5	63.1 (0.9)	0	—	0	—
		119	9	98.4 (4.8)	0	—	1	114.7 (—)	6	59.6 (5.6)	3	69.4 (0.5)	1	72.7 (—)
		121	18	100.5 (4.0)	2	110.3 (0.5)	4	118.8 (7.2)	14	61.0 (4.2)	4	70.2 (0.6)	6	74.5 (3.2)
		124	27	99.4 (5.4)	4	110.7 (1.0)	10	115.0 (2.6)	28	62.2 (4.2)	3	70.4 (0.4)	10	73.9 (2.6)
		128	28	102.4 (5.8)	5	111.5 (0.9)	4	115.3 (1.5)	29	63.5 (4.5)	3	70.2 (0.2)	5	74.3 (1.7)
		131	15	101.4 (6.2)	2	111.2 (0.2)	9	120.1 (4.1)	18	61.6 (7.0)	0	—	8	77.3 (3.7)
		135	4	106.6 (2.9)	1	113.7 (—)	1	120.7 (—)	4	65.8 (1.5)	0	—	2	80.2 (3.5)
		137	2	98.7 (1.4)	0	—	3	120.9 (8.0)	3	62.1 (4.0)	0	—	2	75.2 (0.7)
	8	118	1	90.7 (—)	0	—	0	—	1	59.0 (—)	0	—	0	—
		124	0	—	0	—	0	—	0	—	0	—	0	—
		126	1	105.7 (—)	0	—	0	—	0	—	1	71.0 (—)	0	—
		130	0	—	0	—	0	—	0	—	0	—	0	—
		134	0	—	0	—	0	—	0	—	0	—	0	—
		138	0	104.7 (—)	0	—	0	—	1	59.7 (—)	0	—	0	—
Female	6	112	1	106 (—)	0	—	0	—	1	65.6 (—)	0	—	0	—
		114	2	99.2 (8.7)	0	—	0	—	1	61.0 (—)	0	—	1	72.3(—)
		117	14	99.1 (6.1)	0	—	0	—	12	60.9 (4.6)	3	69.6 (1.0)	0	—
		121	13	100 (5.7)	1	111.3 (—)	1	122.3 (—)	12	61.4 (4.4)	2	70.7 (1.4)	1	75.0 (—)
		124	8	102.6 (5.0)	0	—	3	119.6 (0.7)	6	64.6 (4.0)	0	—	5	74.7 (4.0)
		127	3	103.8 (2.9)	0	—	0	—	2	65.8 (0.2)	1	71.0 (—)	0	—
		129	7	104.9 (3.9)	1	113.3 (—)	0	—	6	64.1 (3.3)	1	72.7 (—)	1	73.0 (—)
	7	115	6	99.2 (1.7)	1	108.7 (—)	1	124.0 (—)	7	62.2 (2.9)	0	—	1	79.3 (—)
		118	4	100.8 (5.6)	0	—	2	114.5 (2.1)	4	62.8 (3.5)	1	69.0 (—)	1	76.3 (—)
		120	20	99.2 (6.0)	3	110.8 (0.8)	0	—	19	61.8 (5.6)	1	70.3 (—)	3	75.4 (3.9)
		123	26	101.8 (4.3)	8	110.5 (1.2)	6	115.7 (3.1)	29	64.3 (3.4)	5	71.2 (0.4)	6	74.1 (1.6)
		127	21	103.0 (4.7)	7	111.3 (1.2)	4	118.5 (4.3)	18	63.1 (4.1)	4	71.1 (0.6)	10	76.2 (3.6)
		130	13	102.8 (4.8)	1	114.3 (—)	0	—	9	65.1 (4.2)	3	71.4 (1.2)	2	76.3 (3.3)
		133	8	104.5 (3.0)	2	115.7 (0)	1	125.3 (—)	8	64.1 (3.0)	2	71.5 (0.2)	1	82.3 (—)
		135	5	99.4 (6.4)	1	113 (—)	2	123.2 (9.2)	6	62.0 (6.6)	0	—	2	79.7 (6.6)
	8	117	1	103.3 (—)	0	—	0	—	1	63.0 (—)	0	—	0	—
		123	0	—	0	—	0	—	0	—	0	—	0	—
		125	1	108.6 (—)	0	—	0	—	1	66.0 (—)	0	—	0	—
		128	1	100.9 (—)	0	—	0	—	1	67.0 (—)	0	—	0	—

Normotensive <90th percentile; pre-hypertensive >90th–<95th percentile; hypertensive >95th percentile.

diameters than boys, while there are no sex differences in AVR.[11] Previous data have shown that parental hypertension,[36] low birth-weight[37] as well as physical inactivity[11,38] are also associated with retinal vessel alterations. These factors are involved in the pathogenesis and development of high BP and should be considered in future research approaches.

One of the strength of the study is the extensive imaging regime. By taking two retinal image of each eye per child, a high degree of accuracy in the measurement of retinal vessel diameters is achieved. A limitation of the study is its relatively small sample size. Although the sample size was estimated to be approximately 290 children, a larger sample would better represent the population and would further limit the influence of outliers. Another limit to our and previous studies is the fact that the cross-sectional design does not examine temporal information. Prospective long-term follow-up studies are necessary to differentiate independent and clinically relevant effects of body composition and BP on retinal microvascular health. Future studies need to clarify whether retinal arteriolar narrowing in young children really predicts cardiovascular outcome and permanent structural alterations in adolescence and adulthood or if it simply reflects

Table 3 Retinal vessel diameter and AVR in relation to 1st and 4th quartile analysis of anthropometric parameters adjusted for age and sex

		CRAE (mu)		CRVE (mu)		AVR	
Quartile	*N*	*Mean (95% CI)*	P	*Mean (95% CI)*	P	*Mean (95% CI)*	P
BMI (kg m^{-2})							
1st, <15.03	98	207.2 (204.4; 209.8)	0.06	232.3 (229.7; 235.0)	0.4	0.89 (0.88; 0.90)	0.2
2nd, 15.03–15.90	98	204.7 (201.9; 207.3)		231.3 (228.7; 234.0)		0.89 (0.88; 0.90)	
3rd, 15.91–17.23	98	207.0 (204.3; 209.6)		232.2 (229.5; 234.9)		0.89 (0.88; 0.90)	
4th, >17.23	97	203.3 (200.6; 206.0)		230.4 (227.7; 233.0)		0.88 (0.87; 0.89)	
BMI z-score							
1st, <−1	43	207.1 (203.1; 211.1)	0.2	233.8 (229.8; 237.8)	0.2	0.89 (0.87; 0.90)	0.9
2nd, −1–1	301	205.5 (204.0; 207.1)		231.5 (229.9; 233.0)		0.89 (0.88; 0.89)	
3rd, >+1	47	203.9 (200.0; 207.7)		230.2 (226.3; 234.0)		0.89 (0.87; 0.90)	
Height (cm)							
1st, <122.7	102	208.1 (205.4; 210.7)	0.03	231.3 (228.7; 234.0)	0.9	0.90 (0.89; 0.91)	0.02
2nd, 122.7–126.1	96	204.7 (202.1; 207.4)		231.4 (228.7; 234.1)		0.89 (0.88; 0.90)	
3rd, 126.2–129.9	96	205.6 (202.9; 208.3)		232.2 (229.5; 234.9)		0.89 (0.88; 0.90)	
4th, >129.9	97	203.4 (200.7; 206.1)		231.3 (228.6; 234.0)		0.88 (0.87; 0.89)	
Weight (kg)							
1st, <23.1	101	207.9 (205.3; 210.6)	0.05	231.2 (228.5; 233.8)	0.8	0.90 (0.89; 0.91)	0.05
2nd, 23.1–25.4	96	206.1 (203.4; 208.7)		234.0 (231.3; 236.7)		0.88 (0.87; 0.89)	
3rd, 25.5–28.1	99	204.8 (202.1; 207.4)		231.0 (228.4; 233.6)		0.89 (0.88; 0.90)	
4th, >28.1	95	203.1 (200.4; 205.9)		230.1 (227.4; 232.9)		0.88 (0.87; 0.89)	
Waist circumference (cm)							
1st, <54.10	98	206.2 (203.6; 208.9)	0.2	232.6 (229.9; 235.3)	0.5	0.89 (0.88; 0.90)	0.5
2nd, 54.10–56.60	98	206.0 (203.3; 208.6)		231.5 (228.8; 234.1)		0.89 (0.88; 0.90)	
3rd, 56.65–60.40	98	206.4 (203.7; 209.0)		231.1 (228.5; 233.8)		0.89 (0.88; 0.90)	
4th, >60.40	97	203.4 (200.7; 206.1)		231.1 (228.4; 233.8)		0.88 (0.87; 0.89)	
Percentage body fat (%)							
1st, <13.11	98	203.9 (201.2; 206.7)	0.7	229.9 (227.2; 232.6)	0.9	0.89 (0.88; 0.90)	0.7
2nd, 13.11–15.76	99	207.1 (204.5; 209.8)		231.1 (228.5; 233.8)		0.90 (0.89; 0.91)	
3rd, 15.77–19.28	97	205.9 (203.2; 208.6)		234.5 (231.9; 237.2)		0.88 (0.87; 0.89)	
4th, >19.28	97	205.0 (202.3; 207.7)		230.7 (228.0; 233.4)		0.89 (0.88; 0.90)	
Waist-to-height ratio							
1st, <0.4324	98	205.5 (202.9; 208.2)	0.7	232.6 (230.0; 235.3)	0.3	0.88 (0.87; 0.90)	0.6
2nd, 0.4325–0.4504	98	205.2 (202.6; 207.9)		231.8 (229.2; 234.5)		0.89 (0.88; 0.90)	
3rd, 0.4505–0.4779	98	206.4 (203.8; 209.1)		230.8 (228.2; 233.5)		0.90 (0.89; 0.91)	
4th, >0.4780	97	204.8 (202.1; 207.5)		231.0 (228.3; 233.7)		0.89 (0.88; 0.90)	
Systolic blood pressure (mm Hg)[a]							
1st, <100.3	102	210.6 (208.0; 213.1)	<0.001	232.7 (230.1; 235.4)	0.2	0.91 (0.90; 0.92)	<0.001
2nd, 100.3–104.3	100	206.4 (203.9; 209.0)		232.0 (229.3; 234.6)		0.89 (0.88; 0.90)	
3rd, 104.4–109.7	92	203.0 (200.3; 205.6)		231.2 (228.4; 233.9)		0.88 (0.87; 0.89)	
4th, >109.7	97	201.6 (198.9; 204.3)		230.3 (227.5; 233.0)		0.88 (0.87; 0.89)	
Diastolic blood pressure (mm Hg)[a]							
1st, <61.3	103	210.0 (207.5; 212.5)	<0.001	232.9 (230.3; 235.5)	0.05	0.90 (0.89; 0.91)	<0.001
2nd, 61.3–65.7	96	206.8 (204.2; 209.4)		230.8 (228.1; 233.5)		0.90 (0.89; 0.91)	
3rd, 65.8–70.4	99	204.8 (202.3, 207.4)		233.0 (230.3; 235.6)		0.88 (0.87; 0.89)	
4th, >70.4	93	199.9 (197.2; 202.5)		229.4 (226.6; 232.1)		0.87 (0.86; 0.88)	

Abbreviations: AVR, arteriolar-to-venular ratio; BMI, body mass index; CI, confidence interval; CRAE, central retinal arteriolar equivalent; CRVE, central retinal venular equivalent.
[a]Additionally adjusted for BMI.

Table 4 Regression analysis of retinal vessel diameter and AVR in relation to anthropometric parameters

		CRAE (mu change per unit)		CRVE (mu change per unit)		AVR (per unit change)	
Parameter	Model	B (95% CI)	P	B (95% CI)	P	B (95% CI)	P
BMI (kg m^{-2})	1	−0.6 (−1.2; 0.09)	0.09	−0.4 (−1.0; 0.3)	0.3	< −0.001 (−0.003; 0.001)	0.4
	2	−0.2 (−0.8; 0.5)	0.6	−0.2 (−0.9; 0.5)	0.5	<0.001 (−0.002; 0.003)	0.9
Height (cm)	1	−0.3 (−0.6; −0.05)	0.02	−0.02 (−0.3; 0.2)	0.9	−0.001 (−0.002; <0.001)	0.01
	2	−0.2 (−0.4; 0.1)	0.2	0.05 (−0.2; 0.3)	0.7	< −0.001 (−0.002; <0.001)	0.1
Weight (kg)	1	−0.4 (−0.7; −0.06)	0.02	−0.2 (−0.5; 0.1)	0.3	< −0.001 (−0.002; <0.001)	0.09
	2	−0.2 (−0.5; 0.2)	0.3	−0.06 (−0.4; 0.3)	0.7	< −0.001 (−0.002; <0.001)	0.5
Waist circumference (cm)	1	−0.2 (−0.4; 0.07)	0.2	−0.07 (−0.3; 0.2)	0.5	< −0.001 (−0.001; <0.001)	0.3
	2	−0.03 (−0.3; 0.2)	0.8	−0.1 (−0.2; 0.2)	0.9	< −0.001 (< −0.001; <0.001)	0.8
Percentage body fat (%)	1	< −0.001 (−0.3; 0.3)	0.9	0.1 (−0.2; 0.4)	0.5	< −0.001 (−0.001; <0.001)	0.4
	2	0.1 (−0.1; 0.4)	0.4	0.2 (−0.1; 0.4)	0.3	< −0.001 (−0.001; <0.001)	0.9
Waist-to-height ratio	1	−7.3 (−39.3; 24.6)	0.7	−9.6 (−41.6; 22.2)	0.6	0.001 (−0.1; 0.1)	0.9
	2	3.5 (−28.4; 35.4)	0.8	−3.9 (−37.0; 29.1)	0.8	0.03 (−0.09; 0.2)	0.7
Systolic blood pressure (mm Hg)	1	−0.4 (−0.6; −0.3)	<0.001	−0.2 (−0.3; 0.005)	0.06	−0.001 (−0.002; < −0.001)	<0.001
	3	−0.2 (−0.4; 0.07)	0.2	−0.1 (−0.4; 0.1)	0.4	< −0.001 (−0.001; <0.001)	0.5
Diastolic blood pressure (mm Hg)	1	−0.6 (−0.7; −0.4)	<0.001	−0.2 (−0.4; 0.04)	0.1	< −0.002 (−0.003; −0.001)	<0.001
	3	−0.4 (−0.7; −0.1)	0.003	−0.06 (−0.3; 0.2)	0.7	< −0.002 (−0.003; < −0.001)	0.003

Abbreviations: AVR, arteriolar-to-venular ratio; BMI, body mass index; CI, confidence interval; CRAE, central retinal arteriolar equivalent; CRVE, central retinal venular equivalent.
Model 1 = adjusted for age and sex; Model 2 = Model 1 plus adjustment for systolic and diastolic blood pressure, Model 3 = Model 1 plus adjustment for BMI, systolic and diastolic blood pressure, respectively.

Table 5 Mean retinal vessel diameters and blood pressure categories

	CRAE (mu)	CRVE (mu)	AVR
	Mean (CI 95%)	Mean (CI 95%)	Mean (CI 95%)
Systolic blood pressure			
Normotensive (N=291)	207.2 (205.6; 208.7)	232.2 (230.6; 233.8)	0.89 (0.89; 0.90)
Pre-hypertensive (N=45)	201.7 (197.8; 205.7)	229.2 (225.2; 233.2)	0.88 (0.87; 0.90)
Hypertensive (N=55)	199.7 (196.2; 203.3)	230.1 (226.5; 233.7)	0.87 (0.86; 0.88)
P-value[a]	0.01	0.2	0.1
P-value[b]	<0.001	0.3	<0.001
Cohen's d[c]	0.4	0.2	0.3
Cohen's d[d]	0.6	0.2	0.5
Diastolic blood pressure			
Normotensive (N=280)	207.5 (205.9; 209.0)	232.1 (230.5; 233.7)	0.90 (0.89; 0.90)
Pre-hypertensive (N=39)	201.7 (197.5; 205.9)	228.8 (224.6; 233.1)	0.88 (0.87; 0.90)
Hypertensive (N=72)	200.0 (196.9; 203.1)	230.8 (227.7; 234.0)	0.87 (0.86; 0.88)
P-value[a]	0.01	0.2	0.1
P-value[b]	<0.001	0.5	<0.001
Cohen's d[c]	0.4	0.2	0.3
Cohen's d[d]	0.6	0.1	0.6

Abbreviations: AVR, arteriolar-to-venular ratio; CI, confidence interval; CRAE, central retinal arteriolar equivalent; CRVE, central retinal venular equivalent; mu, measuring units.
[a]P-value between normotensive and pre-hypertensive groups.
[b]P-value between normotensive and hypertensive groups.
[c]Cohen's d between normotensive and pre-hypertensive groups.
[d]Cohen's d between normotensive and hypertensive groups.

autoregulatory mechanisms in response to higher BP in children. We aim to perform longitudinal studies into adolescence and beyond in the future. Finally, the prevalence of pre-hypertension and hypertension in our study was relatively high. Therefore, we cannot rule out the possibility of a study bias.

On the basis of our results, we would like to conclude that higher BP, even at the level of PHT, seems to be the driving force for microvascular target organ alterations in young school children. Childhood health programs may have to focus more on BP lowering interventions to prevent development of atherosclerosis and manifestation of cardiovascular disease later in life.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Chapter 6 **Publication 2**

Influence of physical fitness and activity behaviour on retinal vessel diameters in primary school children

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Influence of physical fitness and activity behavior on retinal vessel diameters in primary schoolchildren

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Retinal vessel alterations have been shown to be associated with cardiovascular risk factors and physical inactivity as early as childhood. In this context, the analysis of physical activity in children has solely been based on questionnaire assessments. The study aimed to examine the association of physical fitness performance and self-reported physical activity with retinal vessel diameters in young children. Three hundred ninety-one primary schoolchildren [7.3 years (SD 0.4)] were examined in this cross-sectional study. The primary outcome was endurance performance measured with the 20-m shuttle run. The additional tests consisted of a 20-m sprint, jumping sidewards and balancing backwards. Retinal microcirculation was assessed using a static retinal vessel analyzer. Parents completed questionnaires about physical and sedentary activities. Endurance performance was associated with narrower retinal venular diameters [–0.9 (95%CI: –1.8; –0.1) measuring units (mu)/ unit shuttle run, $P = 0.04$] and a higher arteriolar to venular ratio [0.003 (–0.001; 0.006)/unit shuttle run, $P = 0.06$]. The sprint performance was associated with narrower retinal arterioles [4.7 (0.8; 8.6) mu/unit sprint, $P = 0.02$]. Indoor playing activity correlated with narrower retinal venules [–0.04 (–0.07; –0.01) mu/per unit, $P = 0.02$]. Our data suggest that objectively measured endurance performance relates with better retinal vessel health in early childhood.

Retinal vessel diameter analysis is a new noninvasive method to assess cardiovascular risk in adults and children. In adults, changes of retinal arteriolar and venular diameters have been shown to be related to a higher risk of obesity (Wang et al., 2006; Boillot et al., 2013), type 2 diabetes (Wong et al., 2002) and hypertension (Wong et al., 2004; Ikram et al., 2006), increased risk of stroke (Ikram et al., 2006) and a higher cardiovascular mortality rate (Wang et al., 2007). Only few studies have analyzed retinal vessel diameters in children so far (Cheung et al., 2007; Mitchell et al., 2007; Taylor et al., 2007; Hanssen et al., 2012). Childhood obesity and related risk factors have been shown to be associated with retinal venular dilatation and arterial narrowing (Cheung et al., 2007; Taylor et al., 2007; Li et al., 2011; Hanssen et al., 2012; Siegrist et al., 2014). Likewise, higher blood pressure is also associated with arteriolar narrowing and venular dilatation in young children (Mitchell et al., 2007; Li et al., 2011).

Physical activity and inactivity have been shown to influence retinal vessel diameters. A previous report from the Atherosclerosis Risk in Communities Study (ARIC) revealed that active seniors were less likely to have wider retinal venular diameters compared with their sedentary counterparts (Tikellis et al., 2010). In children, higher physical inactivity was independently associated with a lower arteriolar to venular ratio (AVR), primarily because of wider venular diameters (Hanssen et al., 2012). An Australian study examined the influence of self-reported physical activity and screen time on retinal vessels in young children. More time spent in outdoor sporting activities resulted in wider arteriolar diameters. TV watching and computing were associated with narrower arteriolar diameters (Gopinath et al., 2011). Cardiovascular risk factors such as physical inactivity, body mass index (BMI) and high blood pressure have been shown to correlate with changes in retinal vessel diameters in adults and, to a similar extent, in young children. Alterations of retinal vessel diameters seem to occur before common cardiovascular risk factors become evident (Taylor et al., 2007). More research is required, however, to understand the complex relationship between physical activity/inactivity patterns and vascular health early in life.

The data currently available on physical activity and retinal vessel diameters are based on cross-sectional assessments with a questionnaire. A previous study on the association of motor abilities and retinal vessel diameters in children did not include specific endurance performance tests (Siegrist et al., 2014). The effect of endurance capacity and explosive strength, as tested by sprint performance, on the retinal vessel diameters have never been assessed in children before. In adults, a strong correlation between physical fitness levels, defined by the individual anaerobic threshold, and the retinal AVR has been found (Hanssen et al., 2011). Our primary aim was to assess the influence of the 20-m shuttle run performance on retinal vessel diameters in young children within an urban environment. For our primary end point, we hypothesize that the 20-m shuttle run performance is associated with wider retinal arterioles and narrower venules. Furthermore, the influence of additional physical fitness parameters on retinal microvascular health was examined on an explorative basis. Findings for subjective reporting of physical fitness behavior were to be compared with previous findings in young schoolchildren.

Methods

Design and study population

The survey was designed as a large-scale, cross-sectional study. It aimed at monitoring physical fitness tests, body composition, and retinal microvascular health in all first-grade pupils of primary schools in the canton of Basel-Stadt (Switzerland). Teachers and parents were informed *a priori* about the study and its objectives and signed an informed written consent. The study was authorized by the ethics committee of the University of Basel (EKBB, Basel, No. 258/12).

Retinal vessel analysis

Measurements of the retinal microcirculation and the AVR were performed using a Static Retinal Vessel Analyzer (SVA-T, Imedos Systems UG, Jena, Germany). The system allows noninvasive and non-mydriatic online measurements of retinal vessel diameters. It consists of a fundus camera (Topcon TRC NW8) and a software-guided advanced image processing unit (Visualis 2.80, Imedos Systems UG; Hubbard et al., 1999). Two valid photographs were taken from the retina of the left and the right eye, with an angle of 30° and the optic disc in the center (Knudtson et al., 2003). Retinal vessel analysis was performed according to a standardized protocol as described before (Hanssen et al., 2012). Briefly, a single experienced examiner differentiated all retinal arterioles and venules in the outer ring-zone of the automatic software. Diameters were calculated to central retinal arteriolar and venular equivalents (CRAE, CRVE) using the Parr–Hubbard formula explained elsewhere (Hubbard et al., 1999). Using CRAE and CRVE, the AVR was calculated. Vessel diameters are presented in measuring units (mu). In the model of Gullstrand's normal eye, 1 measuring unit relates to 1 µm. One single examiner performed and validated all examinations. Retinal imaging was performed on a separate visit early in the morning in a fasting state. In our study, the correlation coefficient (CC) for CRAE was $r = 0.94$, the coefficient of variation (CV) was 2.1%. For CRVE, the CC was $r = 0.95$ and the CV was 2.0% (AVR: $r = 0.94$ and CV = 2.3%), proofing high reproducibility for all three retinal parameters ($P < 0.001$ each).

Physical fitness testing

Testing was conducted during the physical education lessons at the schools. Before testing, all children performed a standardized 5-min warm-up. Physical fitness testings consisted of a 20-m shuttle run, 20-m sprint, jumping sidewards, and balancing backwards. To measure our primary outcome endurance fitness, a 20-m shuttle run was conducted. The 20-m shuttle run test is a validated test measuring endurance performance by running back and forth for 20 m. The initial running speed was 8.0 km/h with an increase of 0.5 km/h every minute, paced by beeps on a stereo (Van Mechelen et al., 1986; Leger et al., 1988). The individual maximum was reached when the child did not cross the 20-m line at the moment of the beep for two successive 20-m distances. Numbers of "stages" (1 stage ≅ 1 min) performed were counted with a precision of 0.5 stages (Leger et al., 1988). The additional physical fitness performance tests 20-m sprint (Bös et al., 2001; Bös & Tittelbach, 2002), jumping sidewards test (Kiphard & Schilling, 1970; Cools et al., 2009), and balancing backwards test (Kiphard & Schilling, 1970; Cools et al., 2009) were performed according to previously described recommendations.

Assessment of physical activity and screen time

To assess physical activity and screen time, parents were asked to complete a questionnaire by interviewing their child. The questionnaire was developed and established in a previous study in Switzerland (Niederer et al., 2009). Questions included physical activity [defined by time spent by children in vigorous activity, except physical education lessons (min/day)], indoor activity [defined by time spent by children playing indoor (min/day)], outdoor activity [defined by time spent by children playing outdoor (min/day)], indoor and outdoor activity [defined by time spent by children playing indoor plus playing outdoor (min/day)], sport club participation (defined by time participating in a sport club per week), and screen time [defined by time spent by children watching TV, playing video games, and playing on a smartphone (min/day)].

Anthropometrics

Body height was determined to the nearest 0.2 cm using a wall-mounted stadiometer (Seca 206, Seca, Basel, Switzerland) without shoes. Body weight was measured in light clothing and without shoes to the nearest 50 g using an electronic scale (Seca 899, Seca, Basel, Switzerland). BMI was calculated by dividing body weight in kilograms by height in meters squared as described elsewhere (Zahner et al., 2006). Blood pressure (mmHg) was measured after a rest period of 5 min at the right arm, based on recommendations of the American Heart Association (Pickering et al., 2005). In order to reduce interobserver variability, an automated oszillograph (Oscillomate, CAS Medical Systems, Branford, Connecticut, USA) was used. Blood pressure was measured five times. The mean of the three measurements with the smallest variation was further analyzed (National High Blood Pressure Education Program Working Group, 2004).

Statistics

The sample size was estimated based on a previous publication by Hanssen et al. on the influence of endurance exercises on retinal vessel diameters in adults (Hanssen et al., 2011). Based on their study, the effect size (Cohen's d) in adults can be considered as large ($d = 1.2$). In children, the effect size for the influence of a 20-m shuttle run performance on retinal vessel diameters needs to be considered as being smaller. Assuming a moderate effect size, the sample size calculated with the software G-Power using F-tests ($f = 0.25$, power = 0.90% and 5% level of significance) was estimated to be approximately 290 children in total.

Descriptive statistics were made to depict baseline characteristics. Mean (95% CI) CRAE, CR VE, and AVR were compared across the physical fitness first and fourth quartiles by use of univariate analysis of variance. The first group had the lowest physical fitness level and the fourth the highest. Groups were stratified by age and sex. Mean (95% CI) CRAE, CRVE, and AVR were compared across the physical activity and screen time parameters first and fourth quartiles by use of univariate analysis of covariance with age and sex as covariates. Effect size was calculated by Cohen's *d* (small effect: 0.2; medium effect: 0.5; large effect: 0.8; Cohen, 1988). To estimate absolute changes in retinal arteriolar and venular diameters for one unit change of physical fitness parameters, multiple linear regression analysis was applied. Two different models were fitted to adjust for age and sex as well as for BMI and blood pressure. Pearson's correlation coefficient and coefficient of variation were estimated to evaluate the reproducibility of retinal photographs. We used Stata version 12.1 (StataCorp LP, College Station, Texas, USA) for our analyses. 95% confidence intervals were presented for measures of effect to indicate the amount of uncertainty and $P < 0.05$ denoted statistical significance.

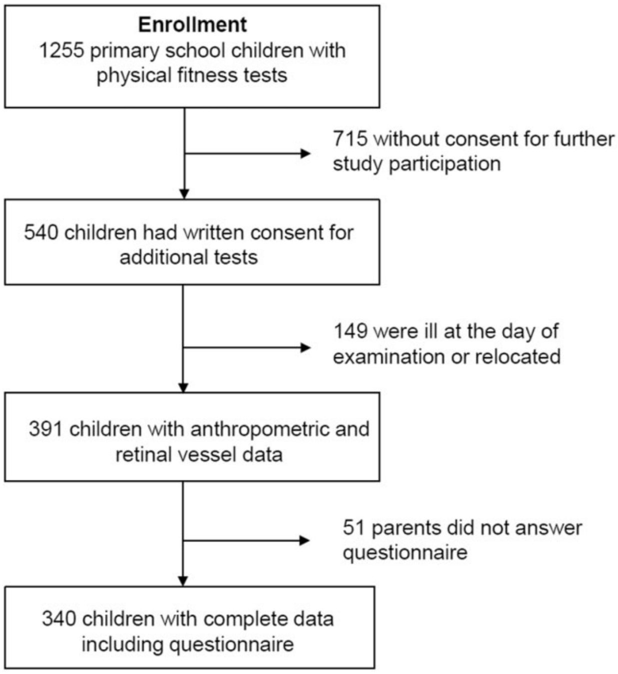

Fig. 1. Flow diagram of children enrolled, screened, and excluded.

Results

From the 1255 children that took part in the study, 540 (43%) were allowed by their parents to attend additional tests on static retinal vessel diameter, blood pressure, and report physical activity levels. One hundred forty-nine children were excluded from the analysis because of illness or relocation. From the remaining 391 children, two valid retinal photographs were taken from both eyes. In 118, only three retinal photographs were gradable, in 45 only two, and in 9 only one picture. No questionnaires were available in 51 children, leaving 340 children with a complete data set (Fig. 1). None of the children included in the analysis presented with chronic or ophthalmic disease or took medication or supplementation. Baseline characteristics of the study population with and without retinal photographs are shown in Table 1.

Comparing the first with the fourth quartile in the 20-m shuttle run, a tendency to narrower venular diameters was found (3.3 mu, $P = 0.09$, $d = 0.3$), favoring the

Table 1. Baseline characteristics of the study population

Parameter	Children with gradable retinal photographs			Children without gradable retinal photographs		
	n	Mean	SD	*n*	Mean	SD
Age	391	7.3	0.4	864	7.5	0.4
Sex						
Female	200			389		
Male	191			475		
Height (cm)	391	126.3	5.3	862	126.7	5.8
Weight (kg)	391	26.1	4.5	862	26.9	5.6
BMI (kg/m^2)	391	16.3	2.1	862	16.6	2.6
20-m Shuttle run (stage)	391	4.4	1.7	843	4.0	1.6
20-m Sprint (s)	391	4.9	0.4	861	5.0	0.4
Jumping sidewards (sum of jump counts)	391	47.3	11.8	861	45.1	11.5
Balancing backwards (sum of steps)	391	39.5	13.4	860	36.4	12.4
Systolic blood pressure (mmHg)	391	104.7	7.9			
Diastolic blood pressure (mmHg)	391	65.7	6.7			
AVR	391	0.89	0.05			
CRAE (mu)	391	205.5	13.7			
CRVE (mu)	391	231.6	13.6			
Vigorous physical activity (min/day)	340	57	41			
Sport club participation (times/week)	340	0.23	0.53			
Indoor activity (min/day)	340	62	43			
Outdoor activity (min/day)	340	76	47			
Screen time (min/day)	340	49	48			
TV time (min/day)	340	32	30			
Computer time (min/day)	340	10	19			
Smartphone time (min/day)	340	8	13			

AVR, arteriolar to venular ratio; BMI, body mass index; CRAE, central retinal arteriolar equivalent; CRVE, central retinal venular equivalent; SD, standard deviation.

group with good shuttle run performances. In the 20-m sprint, faster children had narrower arterioles (5.1 mu, $P = 0.01$, $d = 0.4$) and a reduced mean AVR (0.02, $P = 0.03$, $d = 0.3$). With respect to jumping sidewards and balancing backwards, no associations with retinal vascular parameters were found. Children with a higher level of indoor activity had narrower venular diameters (4.8 mu, $P = 0.01$, $d = 0.4$). And children with a high degree of sport club participation (minutes per week) tended to have narrower venular diameters (2.9 mu, $P = 0.06$, $d = 0.3$) and a higher AVR (0.2, $P = 0.06$, $d = 0.3$) compared with children with no sport club participation. Table 2 shows the retinal vascular parameters of the first to fourth quartile of the physical fitness tests, physical activity, and screen time after adjusting for age and sex.

In the regression analysis, CRVE decreased by –0.9 mu (95% CI: –1.8; –0.1, $P = 0.04$) and the AVR increased by 0.003 (0.001; 0.006, $P = 0.06$) for every stage increase (better endurance performance) in the 20-m shuttle run test after adjusting for sex, age, BMI, and blood pressure. For every second increase in the 20-m sprint (slower sprint performance), CRAE increased by 4.7 mu (0.8; 8.6, $P = 0.02$). In other words, narrower retinal arterial diameters were associated with better performance in the 20-m sprint. However, after adjusting for multiple testing (Bonferroni correction), the results for the 20-m sprint did not remain significant. For every unit increase in indoor activity, CRVE decreased by about –0.04 mu (–0.07; –0.01, $P = 0.02$). These results for the association between retinal vascular parameters, physical fitness, and activity behavior are shown in Table 3.

Discussion

Higher cardiorespiratory endurance performance, measured by use of the 20-m shuttle run test, is independently associated with narrower CRVE and an increased AVR in children as young as 6–8 years of age. These results are in line with similar findings in adults. In adults, the individual anaerobic threshold has been shown to positively correlate with AVR, and a 10-week moderate intensity exercise training improved AVR significantly in lean and obese subjects by means of venular constriction and arteriolar dilatation (Hanssen et al., 2011). In children, wider CRVE is associated with incidence hypertension and obesity (Cheung et al., 2007; Taylor et al., 2007; Li et al., 2011). It therefore seems plausible to conclude that higher endurance performance may have a positive influence on cardiovascular risk reduction and improves microvascular health in young children.

Inflammation is independently associated with increased venular diameters in children as previously described (Hanssen et al., 2012). Similar to patterns in adults, systemic inflammation is an important mechanism for childhood microvascular dysfunction. The anti-inflammatory properties of exercise are likely to be the key mechanism for the beneficial and inverse correlation between endurance fitness and retinal venular diameters. In adults, endurance-trained athletes have been found to have wider retinal arterioles as well as narrower venules (Hanssen et al., 2011). In our cohort of primary schoolchildren, associations of endurance performance with retinal arteriolar dilatation were not evident. These findings seem to indicate that endurance exercise in children may not primarily affect endothelium-dependent retinal arteriolar dilatation but more so retinal venular constriction by its anti-inflammatory properties. Our results are in line with findings of the ARIC in adults, which showed an association of higher physical activity levels with narrower retinal venular diameters (Tikellis et al., 2010). The questionnaire-based survey by Gopinath et al. in young Australian children, however, found a correlation between higher levels of physical activity and wider retinal arterioles (Gopinath et al., 2011).

It can be argued that the changes of retinal vessel diameters are modest across the range of physical fitness performance (about 3 μm). However, it has previously been shown that small increases in retinal venular diameter can already be associated with differences in childhood BMI, metabolic risk factors, and inflammation (Hanssen et al., 2012; Siegrist et al., 2014).

In our study, explosive strength performance as tested by means of the 20-m sprint test is associated with arteriolar narrowing, which is thought to be a marker for increased cardiovascular risk in adults and children alike (Cheung et al., 2007; Taylor et al., 2007; Li et al., 2011; Hanssen et al., 2012; Siegrist et al., 2014). However, the examination of the influence of sprint performance on retinal vessel diameter was explorative in its nature and failed to remain significant after adjusting for multiple testing. Explosive strength is one of the motor skills that are important to achieve healthy motoric development in childhood (Kokštejn et al., 2012). Therefore, the finding is most likely to be a physiologic adaptation to sprint performance rather than a marker for future cardiovascular risk. However, in healthy adults, explosive strength performance, such as lifting hand weights, has been shown to induce acute retinal arteriolar constriction based on the myogenic response to an increase in blood pressure (Jeppesen et al., 2007). Prospective future studies are warranted to clarify whether explosive strength exercise in children, acute or chronic, has negative effects on microvascular function.

Interestingly, indoor activity seems to have a positive influence on retinal venular diameters after adjustment for confounders in this urban cohort. These findings seem to indicate the importance of indoor activities in an urban environment with respect to vascular health. An extra half hour per day spent in indoor activity seems to positively influence the retinal microvascular profile. In a previous Australian study, outdoor activities were

Table 2. Retinal vessel diameter and AVR in relation to first and fourth quartile analysis of physical fitness and activity behavior

Quartile	*n*	CRAE (mu)		CRVE (mu)		AVR	
		Mean (95% CI)	*P*	Mean (95% CI)	*P*	Mean (95% CI)	*P*
20-m Shuttle run (stages)*							
First	132	205.7 (203.4; 208.1)	0.8	233.3 (230.8; 235.7)	0.09	0.88 (0.87; 0.89)	0.2
Second	92	204.8 (201.5; 208.0)		230.9 (228.0; 233.9)		0.89 (0.88; 0.90)	
Third	94	206.1 (203.7; 208.4)		231.0 (228.3; 233.7)		0.89 (0.88; 0.90)	
Fourth (fittest)	73	205.3 (202.1; 208.6)		230.0 (227.4; 232.6)		0.89 (0.89; 0.90)	
20-m Sprint (s)*							
First	82	208.3 (205.3; 211.3)	0.01	232.8 (229.8; 235.7)	0.4	0.90 (0.89; 0.91)	0.03
Second	90	206.5 (203.5; 209.7)		231.6 (228.7; 234.5)		0.89 (0.88; 0.90)	
Third	102	204.9 (202.4; 207.5)		231.1 (228.6; 233.6)		0.89 (0.88; 0.90)	
Fourth (fastest)	117	203.2 (200.7; 205.6)		231.1 (228.4; 233.7)		0.88 (0.87; 0.89)	
Jumping sidewards (jumps)*							
First	108	206.1 (203.4; 208.9)	0.2	232.1 (229.3; 234.8)	0.3	0.89 (0.88; 0.90)	0.7
Second	98	205.4 (202.7; 208.0)		231.8 (229.1; 234.5)		0.89 (0.88; 0.90)	
Third	95	206.7 (203.8; 209.6)		232.3 (229.5; 235.1)		0.88 (0.88; 0.90)	
Fourth	90	203.6 (200.9; 206.4)		229.9 (227.3; 232.5)		0.89 (0.88; 0.90)	
Balancing backwards (steps)*							
First	104	205.0 (201.9; 208.1)	0.9	232.0 (229.3; 234.8)	0.3	0.88 (0.87; 0.89)	0.2
Second	95	206.5 (203.7; 209.3)		231.9 (229.0; 234.8)		0.89 (0.88; 0.90)	
Third	99	205.3 (202.9; 207.6)		232.3 (229.6; 235.0)		0.88 (0.88; 0.89)	
Fourth	93	205.3 (202.6; 208.0)		229.9 (227.3; 232.5)		0.89 (0.88; 0.90)	
Vigorous physical activity†							
First, < 31 min/day	125	204.1 (201.7; 206.5)	0.1	231.1 (228.8; 233.4)	0.3	0.88 (0.88; 0.89)	0.7
Second, 31–60 min/day	134	205.8 (203.5; 208.1)		231.0 (228.8; 233.2)		0.89 (0.88; 0.90)	
Third/fourth, > 60 min/day	81	207.0 (204.0; 209.9)		233.4 (230.6; 236.3)		0.89 (0.88; 0.90)	
Indoor activity†							
First, < 31 min/day	103	206.1 (203.5; 208.7)	0.2	233.3 (230.7; 235.8)	0.01	0.88 (0.87; 0.89)	0.4
Second, 31–60 min/day	157	206.1 (204.0; 208.2)		232.1 (230.1; 234.2)		0.89 (0.88; 0.90)	
Third/fourth, > 60 min/day	80	203.3 (200.3; 206.2)		228.5 (225.6; 231.3)		0.89 (0.88; 0.90)	
Outdoor activity							
First, < 31 min/day	85	206.0 (203.1; 208.8)	0.5	232.1 (229.3; 234.9)	0.4	0.89 (0.88; 0.90)	0.9
Second, 31–60 min/day	114	204.8 (202.4; 207.4)		231.4 (229.0; 233.8)		0.89 (0.88; 0.90)	
Third, 61–120 min/day	108	204.9 (202.3; 207.4)		230.5 (228.0; 232.9)		0.89 (0.88; 0.90)	
Fourth, > 120 min/day	33	208.0 (203.3; 211.6)		234.7 (230.2; 239.2)		0.89 (0.87; 0.91)	
Indoor and outdoor activity							
First, < 61 min/day	51	207.6 (203.9; 211.3)	0.2	233.3 (229.7; 236.9)	0.2	0.89 (0.88; 0.91)	0.8
Second, 61–120 min/day	135	204.7 (202.4; 206.9)		231.6 (229.4; 233.8)		0.88 (0.88; 0.89)	
Third, 121–180 min/day	86	206.2 (203.3; 209.0)		231.7 (228.9; 234.5)		0.89 (0.88; 0.90)	
Fourth, > 180 min/day	68	204.5 (201.3; 207.7)		230.2 (227.1; 233.3)		0.89 (0.88; 0.90)	
Sport club participation							
First, no participation	142	204.7 (202.5; 206.9)	0.9	231.7 (229.6; 233.9)	0.06	0.88 (0.88; 0.89)	0.06
Second, < 45 min/week	28	207.5 (202.5; 212.5)		234.9 (230.1; 239.7)		0.88 (0.87; 0.90)	
Third, 46–105 min/week	91	205.8 (203.0; 208.6)		232.9 (230.2; 235.6)		0.88 (0.88; 0.89)	
Fourth, > 105 min/week	79	205.7 (202.6; 208.7)		228.8 (225.8; 231.7)		0.90 (0.89; 0.91)	
Screen time							
First, < 21 min/day	115	205.7 (203.2; 208.2)	0.9	231.0 (228.6; 233.4)	0.2	0.89 (0.88; 0.90)	0.2
Second, 21–40 min/day	69	204.2 (201.0; 207.4)		230.2 (227.1; 233.3)		0.89 (0.88; 0.90)	
Third, 41–64 min/day	76	205.4 (202.4; 208.5)		232.0 (229.0; 234.9)		0.89 (0.87; 0.90)	
Fourth, > 64 min/day	80	206.2 (203.2; 209.2)		233.4 (230.5; 236.3)		0.88 (0.87; 0.90)	
TV time†							
First, < 21 min/day	131	205.1 (202.8; 207.4)	0.8	231.1 (228.9; 233.4)	0.3	0.89 (0.88; 0.90)	0.4
Second, 21–44 min/day	126	205.6 (203.2; 208.0)		231.0 (228.7; 233.2)		0.89 (0.88; 0.90)	
Third/fourth, > 44 min/day	83	205.8 (202.8; 208.7)		233.4 (230.5; 236.2)		0.88 (0.87; 0.89)	
Computer time‡							
First, no computer time	222	205.9 (204.1; 207.7)	0.6	232.1 (230.4; 233.9)	0.8	0.89 (0.88; 0.89)	0.6
Second/third, 1–29 min/day	45	205.0 (201.0; 209.0)		229.1 (225.2; 233.0)		0.89 (0.88; 0.91)	
Fourth, > 29 min/day	73	204.5 (201.4; 207.6)		231.6 (228.6; 234.6)		0.88 (0.87; 0.90)	
Smartphone time‡							
First, no smartphone time	210	205.5 (203.7; 207.4)	0.7	231.5 (229.8; 233.3)	0.5	0.89 (0.88; 0.90)	0.8
Second/third, 1–10 min/day	48	204.0 (200.2; 207.9)		230.2 (226.5; 234.0)		0.89 (0.87; 0.90)	
Fourth, > 10 min/day	82	206.1 (203.1; 209.0)		232.6 (229.8; 235.5)		0.89 (0.88; 0.90)	

Data are adjusted for age and sex; *P* value across first and fourth quartile.

*Physical fitness cut point differ between sex and age groups.

†A discrimination between the third and the fourth quartile is not possible, since the in-between ranges are exactly the same.

‡A discrimination between the second and the third quartile is not possible, since the in-between ranges are exactly the same.

AVR, arteriolar to venular ratio; CI, confidence interval; CRAE, central retinal arteriolar equivalent; CRVE, central retinal venular equivalent.

Table 3. Regression analysis of retinal vessel diameter and AVR in relation to physical fitness and activity behavior

Parameter	Model	CRAE (mu change per unit)		CRVE (mu change per unit)		AVR (per unit change)	
		B (95% CI)	*P*	B (95% CI)	*P*	B (95% CI)	*P*
20-m Shuttle run (stages)	1	0.1 (−0.7; 1.0)	0.8	−0.7 (−1.5; 0.2)	0.1	0.003 (< −0.001; 0.006)	0.07
	2	−0.07 (−0.9; 0.8)	0.9	−0.9 (−1.8; −0.05)	0.04	0.003 (< −0.001; 0.006)	0.06
20-m Sprint (s)	1	5.0 (1.0; 9.0)	0.01	2.6 (−1.5; 6.6)	0.2	0.01 (−0.003; 0.03)	0.1
	2	4.7 (0.8; 8.6)	0.02	2.8 (−1.3; 6.8)	0.2	0.01 (−0.005; 0.03)	0.2
Jumping sidewards (jumps)	1	−0.06 (−0.2; 0.05)	0.3	−0.06 (−0.2; 0.06)	0.3	< −0.001 (< −0.001; < 0.001)	0.7
	2	−0.06 (−0.2; 0.06)	0.3	−0.06 (−0.2; 0.06)	0.3	< −0.001 (< −0.001; < 0.001)	0.8
Balancing backwards (steps)	1	0.02 (−0.8; 0.1)	0.6	−0.02 (−0.1; 0.08)	0.7	< 0.001 (< −0.001; < 0.001)	0.4
	2	0.01 (−0.09; 0.1)	0.9	−0.03 (−0.1; 0.07)	0.5	< 0.001 (< −0.001; < 0.001)	0.4
Vigorous physical activity (min/day)	1	0.03 (−0.01; 0.06)	0.2	0.02 (−0.01; 0.06)	0.2	< 0.001 (< −0.001; < 0.001)	0.8
	2	0.03 (−0.01; 0.06)	0.2	0.02 (−0.01; 0.06)	0.2	< 0.001 (< −0.001; < 0.001)	0.8
Indoor activity (min/day)	1	−0.04 (−0.07; −0.002)	0.04	−0.04 (−0.07; −0.01)	0.01	< 0.001 (< −0.001; < 0.001)	0.9
	2	−0.03 (−0.07; 0.001)	0.06	−0.04 (−0.07; −0.01)	0.02	< 0.001 (< −0.001; < 0.001)	0.8
Outdoor activity (min/day)	1	0.01 (−0.02; 0.04)	0.7	0.01 (−0.02; 0.04)	0.7	< 0.001 (< −0.001; < 0.001)	0.9
	2	0.01 (−0.02; 0.04)	0.7	0.01 (−0.02; 0.04)	0.7	< 0.001 (< −0.001; < 0.001)	0.9
Indoor and outdoor activity (min/day)	1	−0.01 (−0.03; 0.01)	0.4	−0.01 (−0.03; 0.01)	0.3	< 0.001 (< −0.001; < 0.001)	0.9
	2	−0.01 (−0.03; 0.01)	0.4	−0.01 (−0.03; 0.01)	0.2	< 0.001 (< −0.001; < 0.001)	0.8
Sport club participation (min/week)	1	0.01 (−0.01; 0.02)	0.2	< −0.001 (−0.01; 0.01)	0.9	< 0.001 (< −0.001; < 0.001)	0.1
	2	0.01 (−0.01; 0.02)	0.3	< −0.001 (−0.01; 0.01)	0.9	< 0.001 (< −0.001; < 0.001)	0.2
Screen time (min/day)	1	−0.01 (−0.04; 0.02)	0.5	0.01 (−0.02; 0.03)	0.7	< −0.001 (< −0.001; < 0.001)	0.2
	2	< −0.001 (−0.03; 0.03)	0.9	0.01 (−0.02; 0.04)	0.5	< −0.001 (< −0.001; < 0.001)	0.5
TV time (min/day)	1	0.002 (−0.05; 0.05)	0.9	0.03 (−0.02; 0.08)	0.3	< −0.001 (< −0.001; < 0.001)	0.3
	2	0.02 (−0.03; 0.07)	0.5	0.03 (−0.02; 0.08)	0.2	< −0.001 (< −0.001; < 0.001)	0.5
Computer time (min/day)	1	−0.05 (−0.1; 0.03)	0.2	−0.03 (−0.1; 0.05)	0.5	< −0.001 (< −0.001; < 0.001)	0.4
	2	−0.03 (−0.1; 0.5)	0.5	−0.02 (−0.1; 0.06)	0.6	< −0.001 (< −0.001; < 0.001)	0.8
Smartphone time (min/day)	1	−0.04 (−0.2; 0.07)	0.4	0.01 (−0.1; 0.1)	0.9	< −0.001 (< −0.001; < 0.001)	0.3
	2	−0.03 (−0.1; 0.7)	0.5	0.01 (−0.1; 0.1)	0.9	< −0.001 (< −0.001; < 0.001)	0.4

Model 1 = adjusted for age and sex; model 2 = model 1 plus adjusted for BMI, systolic, and diastolic blood pressure.
AVR, arteriolar to venular ratio; CI, confidence interval; CRAE, central retinal arteriolar equivalent; CRVE, central retinal venular equivalent.

found to correlate with wider retinal arteriolar diameter in 6-year-old children with mixed ethnicity (Gopinath et al., 2011). These different findings may be explained by the geographical disparity, with a less temperate climate and more severe winters in the middle European region (Tucker & Gilliland, 2007). In their study, Gopinath et al. also found an association between screen time and retinal vessel diameters, which was not evident in our study (Gopinath et al., 2011). This may be explained by the difference in average screen time between the two study populations. While our population spent an average of 50 min/day in front of a screen, the Australian population reported an average of 1.9 h/day. It has already been shown that physical activity is better represented by measuring cardiovascular fitness than by physical activity questionnaires (Swift et al., 2013). If a relatively simple endurance performance test such as the 20-m shuttle run test cannot be applied, objective physical activity measurement by accelerometry may be an alternative.

There are limitations to the present study. First, the cross-sectional design does not examine temporal information on the associations. A follow-up study is necessary to deepen the knowledge about associations with cardiovascular disease development until adulthood. Second, compared with children without retinal photographs, our study population was more likely to perform better in the physical fitness tests, was younger, and had a smaller BMI. A selection bias between children with gradable photographs and without may have occurred. No ophthalmic examinations such as intraocular pressure or refraction measurements were performed. Methodologically, magnification of the lens needs to be considered when estimating individual absolute retinal vessel diameters. This does not affect the calculation of AVR. We assumed that the individual reproduction scales were equally and randomly distributed in the sample. The individual variation of refraction is depicted in the statistical spread and is included in the test of significance. Additionally, our data are presented in measuring units (mu), defining 1 mu as 1 μm in Gullstrand's normal eye. One of the strength of the study is the application of an extensive imaging regime by taking two retinal image of each eye per child, thus achieving a high degree of accuracy in the measurement of retinal vessel diameters. Previous studies have analyzed images of one eye only (Cheung et al., 2007; Taylor et al., 2007; Gopinath et al., 2011; Li et al., 2011; Hanssen et al., 2012; Siegrist et al., 2014).

In summary, we have shown for the first time that high cardiovascular fitness performance, measured with the 20-m shuttle run test, is associated with narrower CRVE and a higher AVR and, therefore, with beneficial adaptations of the retinal microvasculature in children. Retinal vessel analysis in children seems to be a feasible diagnostic tool to quantify lifestyle behavior and physical fitness performance on a vascular level. On the basis of our results, we conclude that parents and teachers should focus on improving objective physical fitness measures in young schoolchildren, especially by aerobic-oriented physical activities such as running games, as a means to promote microvascular health.

Perspectives

Our study is the first to assess the association of objectively measured physical fitness performance and self-reported physical activity levels with retinal microvascular health in primary schoolchildren. Our main findings are:

1. A better endurance performance is associated with narrower retinal venular diameters and a lower arteriolar to venular diameter ratio, both reflecting a beneficial microvascular risk profile.
2. In contrast, sprint performance was associated with retinal arteriolar narrowing.
3. Indoor and not outdoor activity seems to have a positive influence on retinal venular diameters in our cohort.

Narrower retinal arteriolar and wider venular diameters are associated with a high incidence of obesity and hypertension in adults and children as well as an increased risk of stroke and a higher cardiovascular mortality rate in adults. Regular aerobic endurance training has previously been shown to beneficially alter retinal vessel diameters in adults. Similar mechanisms seem to apply in children and this work highlights the importance of regular aerobic endurance activities of children to promote vascular health. Longitudinal studies are warranted to assess cause and effect of exercise performance and changes in retinal vessel diameters as well as examining the potential underlying physiological mechanisms.

Key words: Cardiovascular disease prevention, childhood risk factors, retinal microcirculation, exercise performance.

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Chapter 7 **Publication 3**

Examining the association between physical fitness spinal flexibility, spinal posture and reported back pain in 6 to 8 year old children

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Examining the Association between Physical Fitness, Spinal Flexibility, Spinal Posture and Reported Back Pain in 6 To 8 Year Old Children

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Abstract

Background: The prevalence of back pain raises from childhood to adolescence about 18-51%. Therefore, there is a need for early detection of risk factors of back pain. The present study aims to examine the association between physical fitness, spinal flexibility, spinal posture and back pain in primary school children.

Methods: 395 first-graders of the Swiss canton Basel-Stadt (age 7.3 y (SD 0.4)) were examined in the present cross-sectional study. Body mass index, body fat and waist circumference were measured using standard protocols for children. Physical fitness was determined with a test battery consisting of a 20 m shuttle run test, jumping sidewards, 20 m sprints and beam balancing backwards. Spinal flexibility and spinal posture were assessed using the Spinal Mouse MediMouse® (Inclination of the pelvic tilt, the thoracic spine, the lumbar spine and the spinal inclination). Back pain was evaluated by means of a proxy-reported questionnaire.

Results: Children with high versus low spinal flexibility performed better in jumping sidewards (pelvic tilt: $p<0.001$, $d=0.7$; spinal inclination: $p<0.001$, $d=0.8$), 20 m sprint (pelvic tilt: $p=0.03$, $d=0.4$; spinal inclination: $p=0.04$, $d=0.5$) and balancing backwards (pelvic tilt: $p=0.05$, $d=0.5$; spinal inclination: $p<0.001$, $d=0.8$). Boys with a postural insufficiency at pelvic tilt and spinal inclination showed a lower performance in 20 m shuttle running (pelvic tilt: $p=0.01$, $d=0.6$; spinal inclination: $p=0.04$, $d=0.5$) compared to children with a posture, graded as normal. No association between physical fitness, spinal flexibility, spinal posture and back pain was observed (all $p>0.1$).

Conclusions: A high physical fitness level is associated with a higher spinal flexibility in pelvic tilt and spinal inclination in young children. Postural insufficiency was observed in boys with a poor aerobic fitness.

Keywords: Spinal posture; Physical fitness; Back pain; Maximal flexion

Background

Compared to a low prevalence of back pain in children (1-6%), the prevalence of adolescents back pain rises to 18-51% [1]. Numerous risk factors for back pain, such as genetic or constitutional factors, overweight, sex or physical inactivity have been reported to date [2-4]. Reduced spinal flexibility and postural insufficiency have often been associated with low back pain [5,6]. In the Swiss back pain survey from 2011, 80% of the adults reported to suffer at least once a year from back pain. 85% of the reported back pain is not caused by illness or genetic factors but insufficient physical fitness or stress [7]. In 6-9 year old Swiss children 38.4% reported back pain once a week [8]. A previous history of low back pain is often predictive of future back problems [9]. Consequently, there is a need for the early detection of risk factors for back pain.

Studies examining back pain and physical activity in children and adolescents showed particularly conflicting results. While one study showed that physical activity leads to less back pain [10], other studies could not find any association between physical activity nor physical fitness and back pain [3, 11]. Also, different dimensions of physical activity may have different relationships with low back pain [12]. These relationships are dependent on individual factors such as physical fitness or health perceptions [13]. Several studies reported reduced balance performance in adults with low back pain [14]. Several randomized control trials showed that a supervised exercise program improved the average low back pain intensity compared to no treatment [1]. Still studies addressing the relationship between physical fitness, risk factors for back pain and back pain in children are, however, rare, but needed [1]. Therefore, the purpose of our study was to examine the association between physical fitness, spinal flexibility and spinal posture, as risk factors for back pain, and back pain in young children entering primary school.

Methods

Design and study population

The present study was designed as a large scale, cross-sectional trial. Participants for the main study were recruited from the Sportcheck study. Beginning in 2014, this monitoring includes obligatory assessment of physical fitness performed during physical education lessons. From the 1402 children participating in the Sportcheck study, 540 (38.6%) were allowed by their parents to join additional tests on spinal flexibility and posture. 145 children dropped out due to illness at one of the two test dates, relocation, refused to participate in one of the tests or the measurement was rated as invalid. The final analyses sample consisted of 395 children. The study was approved by the local ethics committee of the University of Basel (EKBB, Basel, approval number 258/12). Teachers and parents were a priori informed about the study context. After detailed information about the study content parents signed an informed written consent to the study.

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Anthropometrics

Body height was measured without shoes to the nearest 0.2 cm using a wall-mounted stadiometer (Seca 206, Seca, Basel, Switzerland). Body weight was determined to the nearest 50 g in light clothing and without shoes using an electronic scale (Seca 899, Seca, Basel, Switzerland). BMI was calculated by dividing body weight by height in meters squared. Children were classified as either non-overweight or overweight/obese based on the International Obesity Taskforce (IOTF) reference for children [15]. Waist circumference was measured using a flexible tape at the natural waist (half way between the ribcage and the iliac crest). Skinfold thickness was measured in triplicate to the nearest 0.5 mm with Harpenden calipers (HSK-BI, British Indicators, Burgess Hill, United Kingdom). Calibrated to exert a pressure of 10 g/cm^2 at two sites (triceps and subscapular) based on standard procedures. The two skinfolds were taken to calculate percent body fat [16].

Spinal flexibility and spinal posture

Spinal flexibility and spinal posture were measured with the Spinal Mouse MediMouse® (Idiag, Fehraltorf, Switzerland), a hand-held and computer-assisted electromechanical device that can be used to measure spinal curvature in various positions [17]. This Spinal Mouse was found to be reliable in children (SEM 1.21-13.18°) [18]. The device was guided slightly paravertebral of the spine or along the midline in overweight and obese children, respectively. Starting at the spinous process of the vertebrae prominens (C7) and finishing at the top of the anal crease (approximately S3) [17]. We tested in three positions: standing upright, maximal flexion and maximal extension, as described elsewhere [17]. The range of motion between flexion and extension was calculated as a measure of the spinal flexibility. Flexibility was measured for the angle of inclination of the pelvic tilt, the thoracic spine, the lumbar spine and the spinal inclination (angle subtended between the vertical axis between legs and pelvis and a line joining C7 to the pelvic tilt, Figure 1). In every position three sets of measurements were taken. The mean of the two measurements with the smallest variation was used for further analysis.

The Matthiass-arm-raising test was conducted [19] to assess the capability of the children to control and maintain an upright-standing position for at least 30 seconds with straight arms holding in 90° shoulder flexion. The difference between the spinal curvature before the 30 seconds and after was calculated for the pelvic tilt, the lumbar spine and the spinal inclination. Postural insufficiency was defined as follows: A) extensive shift of the pelvic tilt in the ventral direction, B) increase of the lumbar lordosis or C) an extensively decreased spinal inclination [20] (Figure 1).

Physical fitness testing

Physical fitness testings were conducted in school. All children performed a standardized short 5-minute warm-up. The 20 m shuttle run serves as a validated test [21] to measure aerobic fitness by running forth and back for 20 m, with an initial running speed of 8.0 km/h and an increase of 0.5 km/h every minute, paced by beeps on a stereo. The maximal performance was reached when the child did not cross the 20 m line at the moment of the beep for two consecutive 20 m distances. Numbers of "stages" (1 stage≅1 minute) performed were counted with a precision of 0.5 stages [22]. With the jumping sidewards test speed and coordination was measured [23]. Children repetitively jumped, within 15 seconds, on alternating sides of a wooden strip, as many times as possible. This task had to be performed two times as fast as possible. The sum of the two trials was further analyzed. 20 m sprint times were assessed by electronic timing gates (HL2-31, Tag Heuer, La Chaux-de-Fonds, Switzerland). The test has been shown to be reliable (r=0.9) [24]. Start follows after an acoustic signal, with a precision of 1/100 second. This test had to be performed twice as fast as possible. The faster trial was included in further analysis. This coordination test includes balancing backwards on 3 m long bars with a width of 3, 4.5 and 6 cm. Starting with the 6 cm and ending with the 3.5 cm bar. The number of steps until the child's foot touches the floor was counted. 3 trials were performed for each bar width. The sum of these 9 trials was used for statistical analysis. All tests were found to be reliable [23, 25, 26].

Back pain was assessed with a pain questionnaire [27], distributed at school in coded envelopes and completed by the parents interviewing their child. When back pain was reported, the frequency was asked.

Statistics

The a priori conducted power analysis provided a 95% power (1-β error) to detect medium effect sizes in a two-way analysis of variance with an alpha significance level of 5% when including a total sample size of 252 subjects. Data was tested for normal distribution and variance homogeneity. In addition to descriptive statistics, Students t-test to compare means of two groups was applied to analyze sex differences in baseline characteristics. To compare differences of the segmental flexibility of the spine and the existence of postural insufficiency, two-way analysis of covariance (sex x spine parameter) was used (confidence interval (CI): 95%), with age as a covariate. Physical fitness tests were additionally adjusted for BMI (as a covariate). The spinal flexibility was divided in three groups: low, normal and high spinal flexibility (according to the mean ± standard deviation (sd) for a low flexibility and mean + sd for a high flexibility in both sexes). The data of the Matthiass-arm-raising test were classified in two categories: postural insufficiency and normal posture (according to the mean - standard deviation in both sexes). Effect size was calculated by Cohen's d (small effect: 0.2; medium effect: 0.5; large effect: 0.8) [28]. A multiple linear regression analysis was conducted to estimate the absolute changes in spinal flexibility for one unit change of anthropometrics or physical fitness parameters. The model was adjusted for age, sex in anthropometrics and additionally for BMI in physical fitness tests. Bonferroni post hoc testing was conducted to reveal the direction of the results. We used Stata version 12.1 (StataCorp LP, College Station, TX, USA) for our analyses.

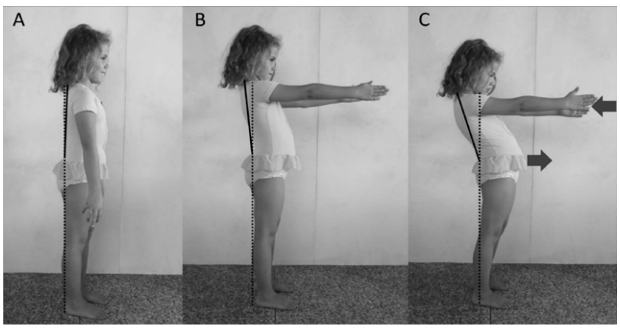

Figure 1: Matthiass-arm-raising-test. (A) The vertical axis between legs and pelvis (dotted line) and the spinal inclination (solid line) standing upright, (B) after 30 seconds with straight arms holding in 90° shoulder flexion graded as normal posture, and (C) graded as postural insufficiency. In C the exemplary postural insufficient child shows an extensive shift of the pelvis in ventral direction and an extensive decreased angle of the inclination (arrows).

Results

In our study population of 395 children, 11% of the children were overweight, 3.4% obese, respectively. Baseline characteristics are shown in Table 1.

Table 2 shows the comparison of sex differences of all spinal parameters.

Anthropometrics, physical fitness and spinal flexibility

Pelvic tilt: Flexibility of the pelvic tilt differed according to waist circumference in both sexes (low: 59.2 cm [95% CI 57.7; 60.7], normal: 58.3 cm [57.6; 59.0], high: 56.5 cm [54.9; 58.0], p=0.04, d>0.3). Post-hoc testing showed no differences (p>0.2). In BMI, height, weight and body fat no difference could be found (p>0.3). Physical fitness differed for the 20 m shuttle run performance in boys, favoring the group with the highest flexibility compared to the one with the lowest (low: 4.3 stages [3.9, 5.0] vs high: 5.3 stages [4.9, 5.9], p=0.04, d=0.6). In jumping sidewards (d=0.7), 20 m sprint (d=0.4) and balancing backwards (d=0.5) both sexes showed a better performance in the group with a high flexibility compared to the group with a low flexibility of the pelvic tilt (Figure 2) (for detailed results see Table A1 Additional File 1). The regression analysis shows that the wider the waist circumference the smaller the flexibility of the pelvic tilt. The better the jumping performance, the faster the children are in the 20 m sprint or the better the balancing performance, the higher is the flexibility of pelvic tilt (Table 4).

Thoracic spine: There were no differences in flexibility of the thoracic spine comparing groups according to anthropometrics and physical fitness (p>0.1) (Table A2 in Additional File 1). The same results were found in the regression analysis (Table 4).

Lumbar spine: Differences were found between BMI and flexibility of the lumbar spine in girls (low: 17.3 kg/m^2 [16.5; 18.0] vs high: 16.2 kg/m^2 [15.3; 16.7], p=0.02, d=0.6 and low: 17.3 kg/m^2 [16.5; 18.0] vs normal: 16.0 kg/m^2 [15.9; 16.5], p=0.03, d=0.6). In the group with low lumbar flexibility, girls were heavier than in the group with the normal flexibility (low: 27.9 kg [26.2; 29.5] vs normal: 25.6 kg [24.8; 26.2] p=0.03, d=0.6).

Parameter	N	Mean	SD
Age (y)	395	7.3	0.4
Sex			
Female	192		
Male	203		
Height (cm)	395	126.3	5.4
Weight (kg)	395	26.2	4.6
BMI (kg/m^2)	395	16.3	2.1
Overweight	43		
Obese	14		
Percentage body fat (%)	395	16.7	5.1
Waist circumference (cm)	395	58.2	6.1
20 m Shuttle Run (stage)	395	4.4	1.7
Jumping sidewards (sum of jump counts)	395	47.1	11.7
20 m Sprint (s)	395	4.9	0.4
Balancing backwards (sum of steps)	395	39.2	13.2
Migrants*	106		

*Both parents from Eastern or Southern European countries, Africa, Asia, Central or South America, or less developed countries

Table 1: Baseline characteristics of the study population.

		Female	Male	p-value	Cohen's d
Parameter*		Mean (95% CI)	Mean (95% CI)		
Pelvic tilt					
	Upright position (U)	21.1 (19.9, 22.3)	18.1 (16.7, 19.5)	<0.01	0.3
	Flexion (F)	53.6 (51.8, 55.5)	52.0 (49.9, 54.2)	0.3	0.1
	Extension (E)	-4.8 (-7.6, -1.9)	-8.3 (-10.5, -6.1)	0.05	0.2
	Range of motion (F-U)	32.5 (30.4, 34.6)	34.0 (31.7, 36.2)	0.4	0.09
	Range of motion (E-U)	-25.9 (-28.5, -23.3)	-26.4 (-28.4, -24.3)	0.8	0.03
	Range of motion (F-E)	58.4 (54.9, 62.0)	60.3 (57.1, 63.5)	0.4	0.08
Thoracic Spine					
	Upright position (U)	33.4 (32.1, 34.7)	35.8 (34.6, 37.0)	<0.01	0.3
	Flexion (F)	56.6 (55.6, 57.6)	56.8 (55.8, 57.7)	0.8	0.02
	Extension (E)	38.5 (36.4, 40.6)	39.2 (37.3, 41.1)	0.6	0.05
	Range of motion (F-U)	23.2 (21.8, 24.6)	21 (19.7, 22.6)	0.02	0.2
	Range of motion (E-U)	5.1 (3.0, 7.2)	3.5 (1.6, 5.4)	0.3	0.1
	Range of motion (F-E)	18.1 (16.0, 20.3)	17.5 (15.6, 19.5)	0.7	0.04
Lumbar Spine					
	Upright position (U)	-33.6 (-35.0, -32.2)	-29.6 (-31.1, -28.1)	<0.001	0.4
	Flexion (F)	32.4 (31.2, 33.7)	32.2 (31.0, 33.4)	0.8	0.03
	Extension (E)	-41.5 (-43.7, -39.3)	-36.0 (-38.0, -33.9)	<0.001	0.4
	Range of motion (F-U)	66.0 (64.7, 67.4)	61.8 (60.4, 63.2)	<0.001	0.4
	Range of motion (E-U)	-7.9 (-9.9, -5.9)	-6.4 (-8.1, -4.7)	0.2	0.1
	Range of motion (F-E)	74.0 (71.7, 76.2)	68.2 (66.1, 70.3)	<0.001	0.4
Spinal inclination					
	Upright position (U)	-1.4 (-1.9, -0.9)	-0.07 (-0.6, 0.4)	<0.001	0.4
	Flexion (F)	92.6 (90.8, 94.3)	90.8 (89.0, 92.6)	0.2	0.1
	Extension (E)	-32.9 (-34.5, -31.3)	-30.7 (-32.0, -29.3)	0.03	0.2
	Range of motion (F-U)	94 (92.2, 95.8)	90.9 (89.0, 92.7)	0.02	0.2
	Range of motion (E-U)	-31.5 (-33.1, -29.9)	-30.6 (-32.0, -29.2)	0.4	0.08
	Range of motion (F-E)	125.5 (122.9, 128.1)	121.5 (119.1, 123.8)	0.03	0.2
Matthiass-Arm-raising test					
	Difference in spinal curvature of the pelvic tilt	-2.3 (-3.3, -1.4)	-1.5 (-2.4, -0.5)	0.2	0.1
	Difference in spinal curvature of the lumbar spine	-3.1 (-4.0, -2.1)	-3.7 (-4.5, -2.8)	0.4	0.09
	Difference in spinal curvature of the spinal inclination	-5.2 (-6.0, -4.4)	-5.7 (-6.5, -5.0)	0.3	0.1

*All values in angular degree°

Table 2: Comparison of sex differences of the spinal parameters measured with a Spinal Mouse in 6 to 8 year old children.

In jumping sidewards, large differences could be found in boys between low and high flexibility, favoring the low group (low: 52.3 jumps [48.1; 56.6] vs high: 44.8 jumps [40.6; 49.1], p=0.05, d=0.6).

Parameter		Difference in spinal curvature of the lumbar spine					
		Postural insufficient (N=51)	Normal (N=344)	pGroup	pSex	pGxS	Cohen's d
BMI (kg/m2)							
	Mean (95% CI)*	16.9 (16.3, 17.5)	16.2 (16.0, 16.5)	0.04	0.7	0.6	0.3
Percentage body fat (%)							
	Mean (95% CI)*	18.3 (16.9, 19.7)	16.5 (16.0, 17.0)	0.02	0.01	0.8	0.4
Height (cm)							
	Mean (95% CI)*	127.7 (126.3, 129.1)	126.1 (125.6, 126.6)	0.04	0.2	0.4	0.3
Weight (kg)							
	Mean (95% CI)*	27.6 (26.4, 28.9)	26.0 (25.5, 26.4)	0.04	0.3	0.6	0.4
Waist circumference (cm)							
	Mean (95% CI)*	59.8 (58.1, 61.4)	57.9 (57.3, 58.6)	0.03	0.3	0.5	0.3
20 m Shuttle Run (stage)							
	Mean (95% CI)**	4.1 (3.7, 4.5)	4.5 (4.3, 4.6)	0.1	<0.001	0.5	0.3
Jumping sidewards (sum of jump counts)							
	Mean (95% CI)**	48.1 (44.9, 51.2)	47.0 (45.7, 48.1)	0.5	0.04	0.3	0.1
20 m Sprint (s)**							
	Mean (95% CI)	4.9 (4.8, 5.0)	4.9 (4.9, 5.0)	0.8	<0.01	0.3	0.03
Balancing backwards (sum of steps)							
	Mean (95% CI)**	41.0 (37.5; 44.5)	39.0 (37.6; 40.2)	0.3	0.03	0.2	0.2

* adjusted for age; **additionally adjusted for BMI

Table 3: Differences in spinal curvature of the lumbar spine in relation to anthropometrics and physical fitness parameters.

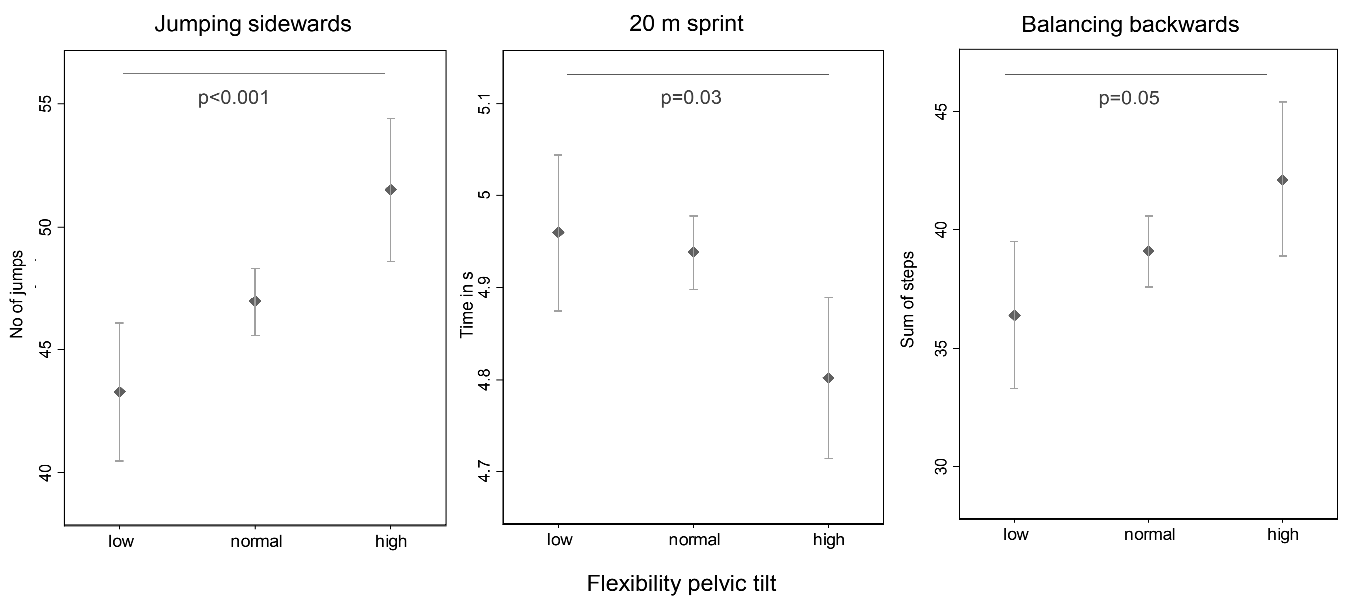

Figure 2: Mean and 95% confidence interval in jumping sidewards, 20 m sprint and balancing backwards according to pelvic tilt flexibility groups (low, normal, high).

In height, weight, body fat, waist circumference, 20 m shuttle run, 20 m sprint and balancing backwards there were no differences in relation to the flexibility of the lumbar spine (p>0.1) (Table A3 in Additional File 1). The regression analysis showed only differences in changes by unit of jumping sidewards, with children with a better jumping performance do have a less flexible lumbar spine (Table 4).

Spinal inclination: Between spinal inclination and anthropometric parameters differences were found in height (low: 128.2 cm [126.8; 129.6], normal: 126.0 cm [125.4; 126.5], high: 126.4 cm [125.0; 127.7], p=0.02, d=0.4), weight (low: 27.8 kg [26.5; 29.0], normal: 26.0 kg [25.4; 26.5], high: 25.9 kg [24.7; 27.1], p=0.03, d=0.4) and in waist circumference (low: 60.6 cm [59.0; 62.3], normal: 57.9 cm [57.2; 58.6], high: 57.0 cm [55.4; 58.7], p<0.01, 0.5=0.6). Physical fitness differed between the groups in 20 m shuttle run in boys (low: 4.2 stages [3.6, 4.7] vs high: 5.6 stages [5.0; 6.1], p<0.01, d=0.9). As shown in Figure 3 jumping sidewards (d=0.8), 20 m sprint (d=0.5) and balancing backwards (d=0.8) differed between the group with the lowest and the group with the highest flexibility of the spinal inclination (Table A4 in Additional File 1).

As shown in the regression analysis (Table 4) children with a higher BMI, a higher weight and a wider waist circumference are less flexible in the inclination of the spine. As well it was found that children that perform better in all of the four physical fitness tests are more flexible in spinal inclination than their peers (Table 4).

Parameter	Pelvic tilt		Thoracic spine		Lumbar spine		Spinal inclination	
	B-coefficent (95%CI)	p	B-coefficent (95%CI)	p	B-coefficent (95%CI)	p	B-coefficent (95%CI)	p
BMI*	-0.6 (-1.8; 0.5)	0.3	0.2 (-0.5; 0.9)	0.6	-0.7 (-1.4; 0.06)	0.07	-0.9 (-1.7; -0.03)	0.04
Percentage body fat*	-0.3 (-0.7; 0.2)	0.3	0.2 (-0.1; 0.5)	0.2	-0.2 (-0.5; 0.07)	0.1	-0.3 (-0.6; 0.06)	0.1
Height*	-0.4 (0.8; 0.1)	0.1	0.1 (-0.2; 0.4)	0.4	-0.02 (-0.3; 0.3)	0.9	-0.3 (-0.6; 0.07)	0.1
Weight*	-0.4 (-0.9; 0.1)	0.1	0.1 (-0.2; 0.4)	0.5	-0.2 (-0.6; 0.09)	0.2	-0.4 (-0.8; -0.06)	0.02
Waist circumference*	-0.6 (-1.0; -0.2)	<0.01	0.2 (-0.1; 0.4)	0.2	-0.01 (-0.3; 0.2)	0.9	-0.4 (-0.7; -0.1)	<0.01
20 m Shuttle Run**	1.0 (-0.6; 2.5)	0.2	0.6 (-0.4; 1.5)	0.2	0.1 (-0.9; 1.2)	0.8	1.2 (0.06; 2.3)	0.04
Jumping sidewards**	0.5 (0.3; 0.7)	<0.01	-0.08 (-0.2; 0.04)	0.2	-0.1 (-0.3; -0.01)	0.03	0.3 (0.2; 0.5)	<0.01
20 m sprint**	-8.7 (-15.8; -1.7)	0.02	-0.7 (-5.1; 3.6)	0.7	3.0 (-1.6; 7.6)	0.2	-6.0 (-11.1; -0.8)	0.02
Balancing backwards**	0.3 (0.1; 0.5)	<0.01	-0.06 (-0.2; 0.06)	0.3	-0.003 (-0.1; 0.1)	0.9	0.3 (0.1; 0.4)	<0.01

* Adjusted for age and sex; **Adjusted for age, sex and BMI

Table 4: Regression analysis of spinal parameters in relation to anthropometrics and physical fitness.

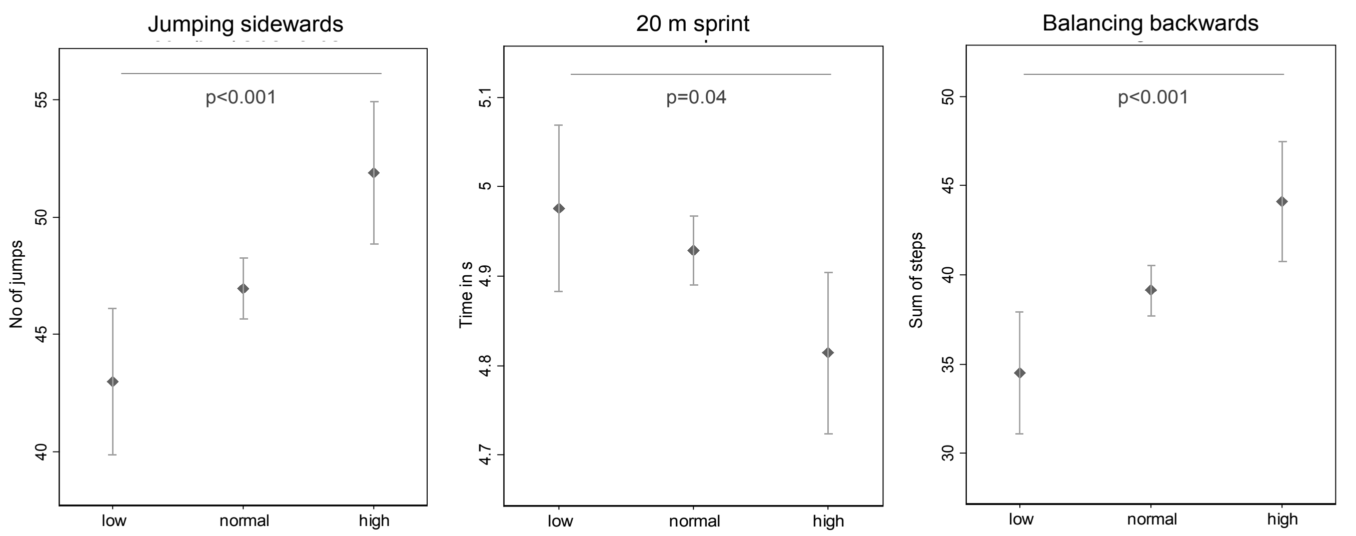

Figure 3: Mean and 95% confidence interval in jumping sidewards, 20 m sprint and balancing backwards according to flexibility groups of spinal inclination (low, normal, high).

Anthropometrics, physical fitness and spinal posture

Pelvic tilt: BMI (postural insufficiency: 17.3 kg/m² [16.3; 18.4] vs normal posture: 16.2 kg/m² [15.9; 16.6], p=0.04, d=0.6), weight (postural insufficiency: 28.7 kg [26.5; 30.8] vs normal posture: 26.3 kg [25.6; 27.0], p=0.04, d=0.5) and 20 m shuttle run performance (postural insufficiency: 4.0 stages [3.2; 4.7] vs normal posture: 4.9 stages [4.7; 5.1], p=0.01, d=0.6) were better in boys with a normal posture in the pelvic tilt compared to boys with a postural insufficiency. As well smaller girls showed more frequently postural insufficiency than their peers (postural insufficiency: 123.2 cm [120.8; 125.6] vs normal posture: 125.7 cm [125.0; 126.5], p=0.05, d=0.5). No differences were shown in the other anthropometric or physical fitness parameters (p>0.3) (Table A5 in Additional File 1).

Lumbar spine: As shown in Table 3 differences between the group with postural insufficiency and the group with a normal posture in the lumbar spine were found in BMI, body fat, height, weight, waist circumference. In 20 m shuttle run a tendency in differences was seen (p=0.1; d=0.3). There were no differences in jumping sidewards, 20 m sprint and balancing backwards (p>0.3) (Table A6 in Additional File 1).

Spinal Inclination: The group comparison between postural insufficiency in the spinal inclination and normal posture revealed differences in boys in 20 m shuttle run favoring the normal group (postural insufficiency: 4.2 stages [3.7; 4.8] vs normal posture: 4.9 stages [4.7; 5.1], p=0.04, d=0.5). The other parameters did not show differences between the two groups (p>0.1) (Table A7 in Additional File 1).

Back pain: One percent of the children reported back pain. No differences in anthropometrics, physical fitness, spinal flexibility, spinal posture concerning back pain could be found (p>0.1).

Discussion

The purpose of this study was to examine the association between physical fitness, spinal flexibility, spinal posture and reported back pain in 6 to 8 year old Swiss children. We found that a high flexibility of the pelvic tilt and the spinal inclination, as well as a low flexibility of the lumbar spine, were associated with better physical fitness in children. The strongest determinant for postural insufficiency was a low performance in 20 m shuttle run test.

Spinal flexibility

Children with a high flexibility in the pelvic tilt and the spinal inclination have a better physical fitness than the children with a low flexibility. Children with a low flexibility in the lumbar spine are better in jumping sidewards than the children with a higher flexibility. As seen in athletes a stiffening of the lumbar spine leads to an improved stabilization of the upper body for functional movements [29]. Studies with back pain patients show, that hypermobility of the lumbar spine leads to more severe back pain [30]. The thoracic spine is anatomically built for stability [31]. Therefore, a lower flexibility in children with higher physical fitness would have been expected. The fact that we could not find any differences between the groups in thoracic flexibility may be because the standardized measurement position (head/neck in a neutral position, hands on the waist) makes it difficult to achieve a full thoracic extension. Similar results have been shown in a previous study with adults [17]. As well we found that children with a higher waist circumference are less flexible in pelvic tilt and spinal inclination. The heavier and the higher the BMI the flexibility of the spinal inclination seem to be limited as well. Since we hypothesize that a less flexible spinal inclination in young age is associated with back pain later in life, these results go in line with a recently published study showing that BMI is associated with low back pain in 9 to 14 year olds [4]. In contrast to boys the flexibility of the spine is higher in girls. This finding has been underlined in other studies in children [10]. Compared with a study that measured the spinal curvature with a Spinal Mouse in 10 year old boys the results of this study are similar [18]. Compared to adults the studies with children show a lower spinal flexibility [17]. This may be because of the considerable restriction of spinal mobility during growth [11].

Spinal posture

In pelvic tilt smaller girls and heavier boys tend to have more often a postural insufficiency, but there were no differences in spinal curvature of the pelvic tilt concerning the BMI. We found that heavier, taller children with a higher BMI, a higher percentage of body fat and a wider waist circumference showed more often postural insufficiency in the lumbar spine during the Matthiass-arm-raising test. As shown in another study to maintain a flat lumbar spine is a margin of safety and important during activities or sports [32]. Hence, it was expected that children with a postural insufficiency are less fit than children with a normal posture. This could only been shown in the 20 m shuttle run test in boys, where children with a postural insufficiency in pelvic tilt and spinal inclination were worse in 20 m shuttle run than their peers with a normal posture. In girls no differences were shown. This could be because the girls in this study were overall worse in the physical fitness parameters than the boys and probably less physically active. It has been shown that children, that are more physically active do have a better physical fitness [33] and less postural insufficiencies [34].

Back pain

Compared to the Swiss spine day data of 2012 (38.4%) only 1 % of the children reported back pain [8]. However, the authors pointed out that the back pain prevalence does not represent the overall prevalence in Switzerland due to selection bias. Our results are in line with a recently published review where 1-6% of the children in a corresponding age group reported low back pain [1]. It has also been shown that the back pain prevalence rises with every year of age [35]. Our data support this hypothesis. The low prevalence likely explains that no correlation between back pain, physical fitness, spinal flexibility or spinal posture could be found.

Strengths and limitations

Compared to Swiss population data [36-38] our sample represents the urban population of Switzerland. However, voluntary study participation may cause selection bias. Compared to the whole population of first-graders of Basel-Stadt a selection bias in the physical fitness level occurred. The participants of this study were significantly better in the 20 m shuttle run in both sexes, in jumping sidewards in boys and in balancing backwards in girls (each $p \leq 0.01$)." The reliability of the Spinal Mouse is high [17] and in this study one trained examiner made all measurements. Therefore, no interexaminer effect has to be considered. Compared to the "gold standard" radiographs studies show, that the Spinal Mouse is valid, except for values recorded at the lumbar segments L4-5 and L5-S1 [17,39]. Those specific segments were not analyzed in the present study. Even if the current literature discusses the radiographs as the "gold standard", no study has ever shown an acceptable reliability for radiographs of the spinal flexibility [17]. Numerous studies showed that a considerable amount of errors occurred in measurements of vertebral angles and their interpretation in radiographs [17,24,40]. Under these circumstances the mean values measured with the Spinal Mouse have been compared to the values measured with various other devices, including radiographs, showed good agreement. Therefore, it has been suggested that the Spinal Mouse is an adequate tool to assess the spinal curvature [17]. Besides the "gold standard" radiographs comes with high costs and considerable patient risk. Up to date only the reliability of the Spinal Mouse measurement has been examined in boys [18]. There is clearly a need for further validity and reliability studies of the Spinal Mouse in children, since most of the research has been conducted in adults so far.

The proxy-reported back pain questionnaire may cause recall bias. But the children were too young to fill out the questionnaire themselves. Further, since the back pain questionnaire was imbedded in the school setting, the accuracy of responding by the parents might have been improved.

Conclusions

Physical fitness is associated with a higher flexibility of the pelvic tilt as well as with a more flexible spinal inclination. There is a tendency towards lower flexibility of the lumbar spine in children with a high physical fitness level. Thus, we conclude that physical fitness has a positive influence on the spinal flexibility. Boys with postural insufficiency tend to have a lower aerobic fitness than their peers. As well postural insufficiency of the lumbar spine is associated with heavy weight, a higher BMI, a wider waist circumference and a higher percentage of body fat. Nevertheless, no association between physical fitness, spinal flexibility, spinal posture and back pain has been found in 6 to 8 year old children.

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Chapter 8 **Publication 4**

The association of socioeconomic factors with physical fitness and activity behaviours, spinal posture and retinal vessel parameters in first graders in urban Switzerland

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The association of socio-economic factors with physical fitness and activity behaviours, spinal posture and retinal vessel parameters in first graders in urban Switzerland

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ABSTRACT

Socio-economic status during childhood has been shown to be a strong predictor of adult health outcome. Therefore, we examined associations of parental educational level, household income and migrant background with physical fitness, spinal flexibility, spinal posture as well as retinal vessel diameters in children of an urban Swiss region. A total of 358 first graders of the Swiss canton Basel-Stadt (age: 7.3, SD: 0.4) were examined. Physical fitness (20 m shuttle run test, 20 m sprint, jumping sidewards and balancing backwards), spinal flexibility and spinal posture (MediMouse®, Idiag, Fehraltdorf, Switzerland) and retinal microcirculation (Static Retinal Vessel Analyzer, Imedos Systems UG, Jena, Germany) were assessed. Parental education, household income, migrant background and activity behaviour were evaluated with a questionnaire. Parental education was associated with child aerobic fitness ($P = 0.03$) and screen time ($P < 0.001$). Household income was associated with jumping sidewards ($P = 0.009$), balancing backwards ($P = 0.03$) and sports club participation ($P = 0.02$). Migrant background was associated with BMI ($P = 0.001$), body fat ($P = 0.03$), aerobic fitness ($P = 0.007$), time spent playing outdoors ($P < 0.001$) and screen time ($P < 0.001$). For spinal flexibility and retinal vessel diameter, no associations were found ($0.06 < P < 0.8$). Low parental education, low household income and a migrant background are associated with poor physical fitness, higher BMI and body fat percentage and low-activity behaviour.

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Parental education; household income; migrant background; back pain; spinal flexibility

Introduction

Children's socio-economic background, which is normally assessed using the parental educational level, parental occupation and income, is considered to be a strong predictor of adult health outcome, including cardiovascular disease (Galobardes, Lynch, & Smith, 2008). An inverse relationship between socio-economic status and adiposity has been shown (Shrewsbury & Wardle, 2008). A European study including eight countries strengthened this finding, but insisted that there are country-specific differences, and that data from more countries are needed (Bammann et al., 2013).

There are only a few studies that address socio-economic status and physical activity or physical fitness in children. An Australian study with 2–16-year-old children did not find a difference in physical activity in children in relation to parental educational level (low vs. middle/high education) (Cameron et al., 2012). In a Dutch study, physical fitness was not different between children with and without social disadvantages (De Greeff et al., 2014). In contrast, a Portuguese study showed that boys with a low parental socio-economic status performed better in muscular and aerobic endurance tests than boys with high socio-economic status (Freitas et al., 2007). In a German study, children with lower socio-economic status had a lower level of physical fitness and were less physically active than children with high parental socio-economic status (Lammle, Worth, & Bos, 2012). Therefore, parental educational level seems to be the most influencing factor of socio-economic status (Finger, Mensink, Banzer, Lampert, & Tylleskar, 2014). To date, only one Swiss study examined the relationship of parental educational level, migrant background, physical activity and physical fitness in children (Burgi et al., 2010). There was no relationship found between physical activity and parental education, but a difference in agility was detected. Children of less educated parents were less agile than children of highly educated parents. This study surveyed preschoolers in a rural region of Switzerland. Current evidence on the relationship between socio-economic status and physical fitness and activity is heterogeneous between countries and there is additional data showing that this relationship may vary between urban and rural regions (Parks, Housemann, & Brownson, 2003). To our knowledge, no study has so far examined the association between parental education level, household income, migrant background and physical fitness and activity in an urban Swiss region.

Children undergo several formative changes (e.g. regarding body composition, motor competency, behaviour and psychosocial aspects) in their transitions from preschool age to first grade (Sigmund, Sigmundova, & El Ansari, 2009). A Czech study found that an increase of school assignments and homework is associated with a decrease of physical activity in children (Sigmund et al., 2009). Therefore, this time of major

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transitions in children's lives needs explicit investigation, particularly regarding children´s physical activity behaviour, physical fitness and health status. In this regard, there are no studies in Swiss population-based cohorts of first graders to date.

Deteriorated vascular health and back pain are considered relevant health issues already in childhood (Hanssen et al., 2012; Kratenova, Zejglicova, Maly, & Filipova, 2007) and may be related to body composition, physical fitness and activity as well as socio-economic status. Recently, it has been shown in a Finnish study that childhood socio-economic status increases the risk of back pain later in life (Lallukka et al., 2014). Reduced spinal flexibility and postural insufficiency have been reported as risk factors for back pain that can be detected early in life (Kratenova et al., 2007; Thomas, Silman, Papageorgiou, Macfarlane, & Croft, 1998). Retinal vessel diameters are a new non-invasive biomarker for microvascular health in adults and children. Thereby, narrower arteriolar and wider venular diameters indicate worse vascular health (Liew, Wang, Mitchell, & Wong, 2008). There is some evidence that physical (in)activity, screen time and cardiometabolic risk factors affect retinal microvasculature in children (Gopinath et al., 2011; Hanssen et al., 2012). A Singapore study found that racial differences in retinal vessel diameters exist among Indian, Malaysian and Chinese children (Cheung et al., 2007). The influence of socio-economic status and migrant background on retinal vessel diameters in young children has never been examined.

In view of the above-mentioned rationales, the aim of our study was to analyse associations among parental educational level, household income and migrant background and physical fitness and physical activity, risk factors for back pain as well as retinal microcirculation in primary schoolchildren in an urban Swiss region.

Methods

Design and study population

Sportcheck was designed as a large-scale, continuous monitoring of physical fitness and body mass index (BMI) of all first graders in the Swiss canton Basel-Stadt. The presented analyses refer to the data obtained in the first year (2014; 1255 children). Sportcheck monitoring includes obligatory assessment of physical fitness performed during physical education lessons. Teachers and parents were a priori informed about the study context and received detailed, oral and written, information on the specific study objectives. The study was approved by the ethics committee of the University of Basel (EKBB, Basel, No. 258/12). All parents of the participating children signed an informed written consent.

Questionnaire

Parents were asked to complete a questionnaire to assess socio-economic factors, parental educational level and household income. They were also asked about their nationality. The questionnaire was previously developed and established in Switzerland (Niederer et al., 2009), and for the present study, it was translated into the seven most spoken languages in Basel-Stadt. Parental educational level was determined in terms of the highest school level completed. Low educational level was defined as only one parent with a vocational training, but no tertiary education. High educational level was defined as both parents having a tertiary education. Tertiles of monthly income per household were taken as levels of household income. Low household income was defined as under CHF 5000/month, the highest level as over CHF 9000/month. Parental migrant background was determined by their country of birth. Families were classified as migrants in case both parents were from Eastern or Southern European countries, Africa, Asia, Central or South America or less developed countries (Kriemler et al., 2010). Parents were asked to complete questions about the activity behaviour of their children by interviewing them about physical activity and screen time. Questions included physical activity (time spent in vigorous activity (min/day)), time spent playing indoor (min/day) and outdoor (min/day), sports club participation (how many times a week and time (min) spent participating in a sports club per week) and screen time (time spent watching TV, playing video games and playing on a smartphone (min/day).

Anthropometrics

Body height was determined using a wall-mounted stadiometer (Seca 206, Seca, Basel, Switzerland), without shoes, to the nearest 0.2 cm. Body weight was measured in light clothing, without shoes, to the nearest 50 g using an electronic scale (Seca 899, Seca, Basel, Switzerland). BMI was calculated by dividing body weight by height in metres squared. Overweight and obesity were classified according to the International Obesity Task Force criteria (Cole, Bellizzi, Flegal, & Dietz, 2000). Children were classified according to their current age and gender as being overweight, if BMI was above 17.5–18.2 kg/m^2 (corresponding to a BMI of 25 kg/m^2 in adults), and as being obese, if BMI was above 20.1–21.1 kg/m^2 (corresponding to a BMI of 30 kg/m^2 in adults). Skinfold thickness was measured in triplicate to the nearest 0.5 mm using Harpenden callipers (HSK-BI, British Indicators, Burgess Hill, United Kingdom) calibrated to exert a pressure of 10 g/cm^2 at two sites (triceps and subscapular), based on standard procedures. These two skinfolds were taken to calculate body fat percentage (Slaughter et al., 1988).

Physical fitness

Physical fitness was tested during the physical education lessons at the children's schools. All children performed a standardised 5-min warm-up, including gymnastic, plyometric and agility exercises before testing. The test battery consisted of a 20 m shuttle run, 20 m sprint, jumping sidewards and balancing backwards.

The 20 m shuttle run is a validated test measuring aerobic fitness by running back and forth between a 20 m distance (Van Mechelen, Hlobil, & Kemper, 1986). The initial running speed was 8.0 km/h with an increase of 0.5 km/h every minute, paced by beeps on an audio system. The test was found to be reliable (r = 0.89) in children aged 6 to 16 years (Leger, Mercier, Gadoury, & Lambert, 1988). The maximal performance was achieved when the child did not cross the

20 m line at the moment of the beep for two consecutive 20 m distances. Numbers of “stages” achieved (1 stage ≅ 1 min) were counted with a precision of 0.5 stages (Committee for the development of sport, 1988).

Speed was measured using a 20 m sprint. Time was assessed by electronic timing gates with a precision of 0.01 s (HL2-31, Tag Heuer, La Chaux-de-Fonds, Switzerland). The start followed an acoustic signal. The faster of the two trials was further analysed. The test is *r*eliable ($r = 0.9$) in children aged 6–11 years (Bös, Tittlbach, Pfeifer, Stoll, & Woll, 2001).

Coordination and muscular endurance was measured with the jumping sidewards test (Kiphard & Schilling, 1970). Previously, the test was found to be reliable in 5–14-year-old children (ICC = 0.95) (Cools, Martelaer, Samaey, & Andries, 2009). The children jumped repeatedly, as many times as possible, within 15 s, with both legs together on alternating sides of a wooden strip. Five single test jumps had to be performed per child prior to testing. This task had to be performed twice as fast as possible. The sum of the two trials was taken for the analysis.

Using a balancing backwards test on 3 m long bars with a starting width of 6 cm, followed by 4.5 cm and 3 cm, respectively, dynamic balance was measured. Children were allowed to balance once forward and once backwards over the widest bar for familiarisation. The number of steps until the child’s foot touched the floor was counted. Three trials were performed for each bar width. The sum of these nine trials was used for analyses. Intra-class correlation (ICC) in 5–14-year-old children was 0.8 (Cools et al., 2009; Kiphard & Schilling, 1970).

Spinal flexibility and spinal posture

Flexibility of the spinal inclination was measured using the Spinal Mouse MediMouse® (Idiag, Fehraltdorf, Switzerland), a handheld electromechanical device (Mannion, Knecht, Balaban, Dvorak, & Grob, 2004). Flexibility was measured three times in two positions: maximal flexion and maximal extension. The range of motion between flexion and extension was calculated as a measure of flexibility in angular degree. The mean of the two measurements with the smallest variation was further analysed.

A Matthiass-arm-raising test was conducted to measure if children have a postural insufficiency (Matthiass, 1966), by measuring the capability of the children to control and maintain an upright-standing position for at least 30 s with straight arms holding in 90° shoulder flexion. The difference between the spinal curvature before the 30 s and after was calculated for the spinal inclination. Postural insufficiency was defined as an extensively decreased spinal inclination (Klee, 1995). Hence, the higher the difference in spinal inclination during the Matthiass-arm-raising test, the worse is the postural control. The Spinal Mouse was found to be reliable in 11-year-old boys (SEM 1.21–13.18°) (Kellis, Adamou, Tzilios, & Emmanouilidou, 2008).

Retinal microcirculation

Retinal vessel diameters were assessed using a Static Retinal Vessel Analyzer (SVA-T, Imedos Systems UG, Jena, Germany). Four valid photographs were taken of the retina of the left and the right eyes, with the optic disc in the centre and at an angle of 30° (Knudtson et al., 2003). Retinal arterioles and venules, crossing an area of 0.5–1 disc diameter from the margin of the optic disc, were identified using special analysing software, identifying retinal vessels in ring-zones (Vesselmap 2, Visualis, Imedos Systems UG). One trained examiner differentiated all retinal arterioles and venules in the outer ring-zone and measured them using the automatic software. Diameters were calculated to central retinal arteriolar and venular equivalents (CRAE, CRVE) using the Parr–Hubbard formula (Hubbard et al., 1999). Using CRAE and CRVE, an arteriolar to venular diameter ratio (AVR) was calculated. The mean results of the right and the left eyes were used for calculations. Correlation coefficients for CRAE, CRVE and AVR were $r \geq 0.94$, and coefficients of variation were between 2.0% and 2.3% in 7-year-old children (Imhof, Zahner, Schmidt-Trucksass, Faude, & Hanssen, 2015).

Statistics

For the sample size estimation (power 0.90, α-error 0.05) a medium effect was assumed according to the review about socio-economic status and adiposity in children (Shrewsbury & Wardle, 2008). The estimated sample size was 230 children. The mean (95% CI) of anthropometric and fitness parameters as well as measurement of risk factors for back pain, retinal microcirculation and activity behaviour were compared across having a migrant background and the different levels of parental education and household income by use of univariate analysis of covariance (ANCOVA) with age, sex and BMI as covariates. In the second model, the additional covariates, parental education level, household income and migrant background, were implemented. Effect size for the difference between the low and the high groups was calculated by Cohen’s *d* (small effect: 0.2; medium effect: 0.5; large effect: 0.8) (Cohen, 1988). Bonferroni post hoc testing was conducted to reveal the direction of the results. Pearson´s product moment correlations were calculated to assess associations between physical fitness and activity parameters as well as retinal microcirculation and spinal posture. Thresholds for correlations were 0.1, 0.3, 0.5, 0.7 and 0.9 indicating small, moderate, large, very large and extremely large relationships, respectively (Hopkins, Marshall, Batterham, & Hanin, 2009). Stata version 12.1 (StataCorp LP, College Station, TX, USA) was used for analyses. Confidence intervals of 95% were presented for measures of effect to indicate the amount of uncertainty.

Results

From 1255 children that took part in the Sportcheck study, 540 (43 %) were allowed by their parents to join additional tests on spinal flexibility and retinal vessel analysis and to complete parental questionnaires. A total of 131 children were not tested due to acute illness or relocation. Parents of 51 children did not answer the questionnaire. Therefore, from the full cohort, 358 children remained for the present analyses (Figure 1). Fifty-one per cent of the 358 children participating

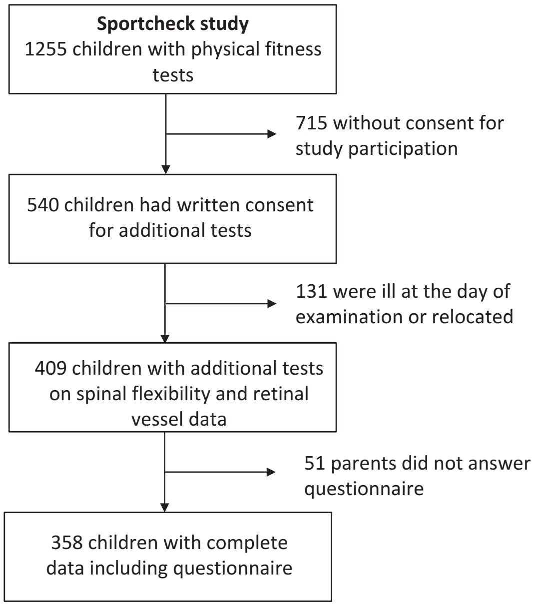

Figure 1. Flow diagram of children enrolled, screened and excluded.

Table 1. Baseline characteristics of the study population.

Parameter	*N*	Mean	SD
Age	358	7.3	0.4
Sex	358		
Female	184		
Male	174		
Height (m)	358	1.26	0.05
Weight (kg)	358	26.0	4.4
BMI (kg/m^2)	358	16.3	2.0
Body fat (%)	340	16.6	4.8
20 m Shuttle Run (stage)	345	4.5	1.7
20 m Sprint (s)	356	4.9	0.4
Jumping sidewards (sum of jump counts)	357	47.9	11.9
Balancing backwards (sum of steps)	358	40.0	13.1
Flexibility spinal inclination (angular degree)	358	124.7	17.9
Difference in spinal inclination (angular degree)	350	−5.5	5.3
CRAE (µm)	358	205.7	14.1
CRVE (µm)	358	231.9	13.2
AVR	358	0.89	0.05
Vigorous physical activity (min/day)	358	58	42
Playing indoor (min/day)	358	63	44
Playing outdoor (min/day)	358	76	47
Sports club participation (min/week)	358	71	101
Screen time (min/day)	358	48	46
Migrant background: migrant*/non-migrant	87/271		
%	24/76		
Parental education: low**/medium/high	47/93/180		
%	15/29/56		
Household income: low/medium/high	78/114/130		
%	24/36/40		

Notes: AVR, arteriolar-to-venular ratio; CRAE, central retinal arteriolar equivalent; CRVE, central retinal venular equivalent
*Both parents from Eastern or Southern European countries, Africa, Asia, Central or South America, or less developed countries
**Only one parent with a vocational training, but no tertiary education.

in the study were girls. Baseline characteristics are shown in Table 1.

Parental education level

Twenty-eight per cent of the children were overweight with low and 6% with high parental education level. Eleven per cent of children were obese with low and 2% with high parental education level. Comparing the lowest parental education level group with the highest in the univariate model, a difference was found in physical fitness, health and activity behaviour parameters (Table 2), favouring the group with highly educated parents. After adjusting for household income and migrant background, differences were found in the 20 m shuttle run, in spinal posture and in screen time (model 2).

Household income

As shown in Table 3 (model 1) BMI, body fat, 20 m shuttle run, jumping sidewards, balancing backwards, sports club participation and screen time were different in children with a low compared to children with a high household income, favouring the group with a high household income. Eighteen per cent of the children with a low and 7% with a high parental household income were overweight, 9% and 2% were obese, respectively. Retinal venular diameters also differed between the levels of household income. Adjusted for parental education and migrant background, jumping sidewards, balancing backwards, as well as sports club participation differed between children with a low compared to a high parental household income (model 2).

Migrant background

About 21%/6% of the children with migrant background and only 7%/1% of the children without migrant background were overweight/obese. Differences in anthropometric, physical fitness and activity behaviour between children with a migrant background and non-migrants are shown in Table 4. After adjusting for parental education and household income, differences were found between non-migrants and migrants in BMI, body fat, 20 m shuttle run, time spent playing outdoor and screen time (model 2), favouring the non-migrant group.

A very large correlation was observed between BMI and body fat percentage. Body composition was moderately associated with shuttle run and sprint performance. There were moderate to large correlations among the physical fitness parameters, large correlations among retinal vessel diameters and moderate correlations of physical activity as well as indoor activity with outdoor activity. All other correlations were either small or negligible (Table 5).

Discussion

This study aimed to analyse associations between socio-economic factors and physical fitness, physical activity, risk factors for back pain as well as retinal microcirculation in primary schoolchildren. The present results suggest that children with better educated parents had better aerobic fitness and spent less time in front of a screen. Children living in a household with a higher income showed better motor coordination and participated more frequently in a sports club. Children with a migrant background had a higher BMI and body fat content, spent more time in front of a screen, had a worse aerobic fitness and played less time outdoors than their non-migrant peers. The socio-economic factors of parental

Table 2. Differences in health parameters, physical fitness and activity behaviour between low, medium and high parental education.

Parameter	Model	Parental education* Low (*N* = 47)	Medium (*N* = 128)	High (*N* = 180)	*P*	Cohen's *d*†
BMI (kg/m²)**						
Mean (CI 95%)	1	17.1 (16.6; 17.5)	16.5 (16.3; 16.7)	15.9 (15.6; 16.1)	<0.001	0.7
Mean (CI 95%)	2	16.8 (16.2; 17.3)	16.4 (16.2; 16.7)	16.1 (15.7; 16.4)	0.06	0.3
Body fat (%)**						
Mean (CI 95%)	1	18.7 (17.6; 19.7)	17.1 (16.6; 17.8)	15.6 (14.9; 16.3)	<0.001	0.7
Mean (CI 95%)	2	17.5 (16.2; 18.8)	16.9 (16.3; 17.5)	16.2 (15.5; 17.0)	0.1	0.3
20 m Shuttle Run (stages)						
Mean (CI 95%)	1	3.7 (3.4; 4.1)	4.3 (4.1; 4.5)	4.9 (4.7; 5.1)	<0.001	0.8
Mean (CI 95%)	2	4.0 (3.6; 4.5)	4.4 (4.2; 4.5)	4.7 (4.4; 4.9)	0.03	0.4
20 m Sprint (s)						
Mean (CI 95%)	1	4.96 (4.89; 5.04)	4.92 (4.88; 4.96)	4.88 (4.83; 4.93)	0.1	0.3
Mean (CI 95%)	2	4.96 (4.87; 5.05)	4.93 (4.89; 4.98)	4.91 (4.85; 4.96)	0.4	0.1
Jumping sidewards (sum of jumps)						
Mean (CI 95%)	1	44.2 (41.5; 46.8)	46.9 (45.6; 48.3)	49.7 (48.1; 51.3)	<0.01	0.5
Mean (CI 95%)	2	45.8 (42.7; 48.9)	47.1 (45.7; 48.6)	48.4 (46.7; 50.2)	0.2	0.2
Balancing backwards (sum of steps)						
Mean (CI 95%)	1	38.3 (35.4; 41.2)	39.6 (38.1; 41.1)	40.9 (39.2; 42.7)	0.2	0.2
Mean (CI 95%)	2	40.7 (37.2; 44.2)	40.2 (38.5; 41.8)	39.6 (37.7; 41.6)	0.7	0.08
Spinal flexibility (°)						
Mean (CI 95%)	1	122.5 (118.4; 126.6)	124.1 (122.0; 126.2)	125.7 (123.2; 128.2)	0.2	0.2
Mean (CI 95%)	2	121.3 (116.4; 126.2)	123.5 (121.2; 125.8)	125.7 (122.9; 128.5)	0.2	0.2
Difference in spinal inclination (°)						
Mean (CI 95%)	1	−7.5 (−8.8; −6.3)	−6.1 (−6.7; −5.5)	−4.7 (−5.4; −3.9)	0.01	0.6
Mean (CI 95%)	2	−7.5 (−9.1; −5.9)	−6.1 (−6.8; −5.4)	−4.6 (−5.5; −3.8)	0.007	0.5
AVR						
Mean (CI 95%)	1	0.88 (0.87; 0.90)	0.89 (0.88; 0.89)	0.89 (0.88; 0.90)	0.4	0.2
Mean (CI 95%)	2	0.89 (0.88; 0.91)	0.89 (0.88; 0.90)	0.88 (0.88; 0.89)	0.4	0.2
CRAE (µm)						
Mean (CI 95%)	1	207.1 (203.9; 210.3)	206.1 (204.5; 207.7)	205.1 (203.1; 207.1)	0.3	0.2
Mean (CI 95%)	2	208.3 (204.4; 212.2)	206.4 (204.6; 208.3)	204.5 (202.3; 206.8)	0.2	0.3
CRVE (µm)						
Mean (CI 95%)	1	234.8 (231.8; 237.8)	232.6 (231.1; 234.2)	230.5 (228.6; 232.3)	0.03	0.4
Mean (CI 95%)	2	233.6 (229.9; 237.2)	232.4 (120.7; 234.1)	231.3 (229.3; 233.4)	0.4	0.2
Physical activity (min/day)						
Mean (CI 95%)	1	60 (51; 70)	59 (54; 64)	57 (52; 63)	0.7	0.08
Mean (CI 95%)	2	54 (42; 66)	57 (52; 63)	60 (53; 67)	0.5	0.1
Indoor activity (min/day)						
Mean (CI 95%)	1	65 (55; 75)	64 (59; 69)	63 (57; 69)	0.8	0.05
Mean (CI 95%)	2	66 (54; 78)	64 (59; 70)	63 (56; 70)	0.7	0.07
Outdoor activity (min/day)						
Mean (CI 95%)	1	71 (60; 81)	74 (89; 80)	78 (71; 84)	0.3	0.2
Mean (CI 95%)	2	73 (60; 85)	74 (68; 80)	75 (68; 83)	0.8	0.04
Sports club participation (in %)						
Mean (CI 95%)	1	39 (28; 50)	52 (47; 58)	66 (59; 73)	<0.001	0.6
Mean (CI 95%)	2	48 (35; 62)	55 (49; 61)	52 (54; 69)	0.1	0.3
Sports club participation (min/week)						
Mean (CI 95%)	1	55 (32; 78)	67 (55; 79)	79 (65; 93)	0.1	0.3
Mean (CI 95%)	2	69 (43; 95)	70 (58; 82)	71 (56; 85)	0.9	0.02
Screen time (min/day)						
Mean (CI 95%)	1	80 (71; 90)	57 (52; 62)	33 (27; 39)	<0.001	1.2
Mean (CI 95%)	2	74 (63; 86)	56 (50; 61)	37 (31; 44)	<0.001	0.9

Note: P-value across the low and the high groups; model 1: adjusted for age, sex and BMI; model 2: model 1 plus household income and migrant background; *low: only one parent with a vocational training, but no tertiary education, high: both parents with tertiary education; ** adjustment was done without children's BMI; † effect size for the difference between the low and the high groups.

education, household income and migrant background have been found to influence body composition as well as physical fitness and activity in primary schoolchildren of the canton Basel-Stadt. Health-related parameters like retinal vessel diameters and spinal mobility were also affected but to a lesser extent.

A main observation in the present study is that children with better educated parents were faster in the 20 m shuttle run test than children of low educated parents. This finding is in line with a German study that measured cardiovascular fitness in adolescents with a sub-maximal cycle ergometer test (Finger et al., 2014). These authors reported that parental education is more strongly associated with aerobic fitness in adolescents than household income. The same holds true for screen time, as children of better educated parents spent less time in front of a screen than children of low educated parents. This is consistent with a review that reported a negative association between parental education level and children's screen time (Hoyos Cillero & Jago, 2010). We observed a small correlation between screen time and shuttle run performance. However, whether there is a causal relationship between both variables cannot be stated with certainty on the basis of the present results. When not adjusting for the other socio-economic factors, parental education was also associated with the children's spinal posture. Children from parents with low education level are less capable to control and maintain an upright-standing position

Table 3. Differences in health parameters, physical fitness and activity behaviour among low, medium and high household income.

Parameter	Model	Household income* Low (*N* = 78)	Medium (*N* = 114)	High (*N* = 130)	*P*	Cohen's *d*†
BMI (kg/m^2)**						
Mean (CI 95%)	1	16.7 (16.3; 17.1)	16.3 (16.1; 16.6)	16.0 (15.6; 16.3)	0.008	0.3
Mean (CI 95%)	2	16.2 (15.8; 16.7)	16.3 (16.0; 16.5)	16.3 (16.0; 16.7)	0.8	0.04
Body fat (%)**						
Mean (CI 95%)	1	18.4 (17.4; 19.3)	16.9 (16.4; 17.4)	15.4 (14.6; 16.2)	<0.001	0.6
Mean (CI 95%)	2	17.5 (16.4; 18.6)	16.7 (16.2; 17.3)	16.0 (15.2; 16.8)	0.07	0.3
20 m shuttle run (stages)						
Mean (CI 95%)	1	3.9 (3.6; 4.2)	4.4 (4.2; 4.5)	4.9 (4.6; 5.1)	<0.001	0.7
Mean (CI 95%)	2	4.2 (3.9; 4.6)	4.4 (4.3; 4.6)	4.6 (4.4; 4.9)	0.1	0.2
20 m sprint (s)						
Mean (CI 95%)	1	4.98 (4.92; 5.05)	4.93 (4.90; 5.0)	4.88 (4.83; 4.93)	0.02	0.3
Mean (CI 95%)	2	4.96 (4.88; 5.03)	4.93 (4.89; 4.96)	4.90 (4.84; 4.96)	0.3	0.1
Jumping sidewards (sum of jumps)						
Mean (CI 95%)	1	43.6 (41.4; 45.8)	47.0 (45.7; 48.2)	50.3 (48.6; 52.1)	<0.001	0.6
Mean (CI 95%)	2	44.6 (42.1; 47.2)	47.2 (46.0; 48.4)	49.8 (47.8; 51.8)	0.009	0.4
Balancing backwards (sum of steps)						
Mean (CI 95%)	1	36.7 (34.3; 39.2)	39.4 (38.0; 40.8)	42.1 (40.1; 44.1)	0.003	0.4
Mean (CI 95%)	2	37.2 (34.3; 40.0)	39.6 (38.2; 41.0)	41.9 (39.7; 44.2)	0.03	0.3
Spinal flexibility (°)						
Mean (CI 95%)	1	122.5 (119.1; 126.0)	124.1 (122.1; 126.0)	125.6 (122.7; 128.4)	0.2	0.2
Mean (CI 95%)	2	122.5 (118.5; 126.5)	124.1 (122.1; 126.1)	125.7 (122.5; 128.9)	0.3	0.2
Difference in spinal inclination (°)						
Mean (CI 95%)	1	−5.8 (−6.9; 4.8)	−5.5 (−6.1; −4.9)	−5.2 (−6.1; −4.4)	0.4	0.1
Mean (CI 95%)	2	−4.8 (−6.0; −3.5)	−5.4 (−6.0; −4.8)	−6.0 (−7.0; −5.1)	0.2	0.2
AVR						
Mean (CI 95%)	1	0.88 (0.87; 0.89)	0.89 (0.88; 0.89)	0.89 (0.89; 0.90)	0.06	0.2
Mean (CI 95%)	2	0.88 (0.87; 0.89)	0.89 (0.88; 0.89)	0.89 (0.88; 0.90)	0.1	0.2
CRAE (μm)						
Mean (CI 95%)	1	206.5 (203.8; 209.3)	205.8 (204.3; 207.4)	205.1 (202.9; 207.3)	0.5	0.1
Mean (CI 95%)	2	206.1 (202.9; 209.3)	205.8 (204.2; 207.3)	205.4 (202.9; 208.0)	0.8	0.04
CRVE (μm)						
Mean (CI 95%)	1	235.2 (232.6; 237.7)	232.5 (231.0; 233.9)	229.8 (227.7; 231.9)	0.004	0.5
Mean (CI 95%)	2	234.4 (231.4; 237.4)	232.4 (230.9; 233.8)	230.3 (228.0; 232.7)	0.08	0.3
Physical activity (min/day)						
Mean (CI 95%)	1	64 (56; 72)	59 (55; 64)	54 (48; 61)	0.1	0.3
Mean (CI 95%)	2	63 (54; 73)	59 (54; 64)	55 (47; 62)	0.2	0.2
Playing indoor (min/day)						
Mean (CI 95%)	1	63 (54; 71)	63 (59; 68)	64 (57; 71)	0.8	0.03
Mean (CI 95%)	2	63 (53; 73)	64 (59; 68)	64 (57; 72)	0.8	0.02
Playing outdoor (min/day)						
Mean (CI 95%)	1	74 (65; 83)	75 (70; 80)	75 (68; 82)	0.8	0.02
Mean (CI 95%)	2	79 (69; 90)	75 (70; 80)	71 (53; 79)	0.3	0.2
Sports club participation (in %)						
Mean (CI 95%)	1	44 (35; 54)	56 (50; 61)	67 (59; 75)	0.01	0.5
Mean (CI 95%)	2	50 (39; 61)	56 (51; 62)	63 (54; 71)	0.2	0.3
Sports club participation (min/week)						
Mean (CI 95%)	1	49 (31; 67)	67 (57; 77)	85 (70; 100)	0.06	0.4
Mean (CI 95%)	2	47 (27; 69)	67 (27; 77)	86 (70; 103)	0.02	0.4
Screen time (min/day)						
Mean (CI 95%)	1	67 (58; 75)	52 (47; 57)	37 (30; 44)	<0.001	0.7
Mean (CI 95%)	2	48 (38; 57)	49 (44; 53)	49 (42; 57)	0.8	0.03

Note: P-value across the low and the high group; model 1: adjusted for age, sex and BMI; model 2: model 1 plus parental education level and migrant background, *low household income was defined as an income till CHF 5000/month, the highest level as over CHF 9000/month; ** adjustment was done without children's BMI; † effect size for the difference between the low and the high group.

for 30 s than children with well-educated parents. Children's postural insufficiency is a risk factor for back pain later in life and therefore important to detect in an early stage (Lallukka et al., 2014). We like to assume that parental education plays a key role in the development of postural insufficiency and strongly influences body composition and physical fitness.

Household income has a notable influence on balancing backwards and jumping sidewards. One explanation is that children participating in organised sport have a higher level of motor coordination than children not attending organised sport (Vandorpe et al., 2012). This point is strengthened as household income is also positively associated with participation in organised sport in our study, which is possibly due to the fact that participating in sports clubs can be expensive in Switzerland. In addition, the small correlation between sprinting and jumping abilities and sports club participation may further strengthen this speculation.

The retinal venular vessel diameters differ between the household income groups after adjusting for age, sex and BMI. Children with a low household income have wider retinal venular vessel diameters than children with a high household income. As shown in adults, wider retinal venules and smaller arterioles predicted increased risk of coronary heart disease mortality (Wang et al., 2007). It has also been shown that a disadvantaged socio-economic status is associated with a greater risk of death from cardiovascular disease in adults

Table 4. Differences in health parameters, physical fitness and activity behaviour between children of migrant and non-migrant parents.

Parameter	Model	Migrant background: Non-Migrants (*N* = 271)	Migrants* (*N* = 87)	*P*	Cohen's *d*†
BMI (kg/m²)**					
Mean (CI 95%)	1	16.0 (15.8; 16.2)	17.1 (16.7; 17.6)	<0.001	0.6
Mean (CI 95%)	2	16.0 (15.8; 16.3)	17.0 (16.5; 17.5)	0.001	0.5
Body fat (%)**					
Mean (CI 95%)	1	15.9 (15.4; 16.5)	18.7 (17.7; 19.7)	<0.001	0.6
Mean (CI 95%)	2	16.2 (15.6; 16.9)	17.8 (16.6; 19.0)	0.03	0.3
20 m shuttle run (stages)					
Mean (CI 95%)	1	4.8 (4.6; 4.9)	3.8 (3.5; 4.1)	<0.001	0.7
Mean (CI 95%)	2	4.6 (4.4; 4.8)	4.0 (3.7; 4.4)	0.007	0.4
20 m sprint (s)					
Mean (CI 95%)	1	4.89 (4.85; 4.92)	4.97 (4.90; 5.04)	0.06	0.2
Mean (CI 95%)	2	4.91 (4.87; 4.96)	4.96 (4.87; 5.04)	0.4	0.1
Jumping sidewards (Sum of jumps)					
Mean (CI 95%)	1	48.7 (47.3; 50.1)	45.3 (42.8; 47.8)	0.02	0.3
Mean (CI 95%)	2	47.8 (46.4; 49.3)	47.1 (44.3; 49.9)	0.7	0.06
Balancing backwards (Sum of steps)					
Mean (CI 95%)	1	40.9 (39.4; 42.4)	37.1 (34.4; 39.8)	0.01	0.3
Mean (CI 95%)	2	40.4 (38.; 42.0)	38.6 (34.5; 41.8)	0.4	0.1
Spinal flexibility (°)					
Mean (CI 95%)	1	124.3 (122.1; 126.4)	126.2 (122.4; 130.0)	0.4	0.1
Mean (CI 95%)	2	123.2 (120.9; 125.5)	127.8 (123.4; 132.3)	0.09	0.2
Difference in spinal inclination (°)					
Mean (CI 95%)	1	−5.2 (−5.8; −4.5)	−6.7 (−7.9; −5.6)	0.02	0.3
Mean (CI 95%)	2	−5.2 (−5.9; −4.5)	−6.5 (−7.8; −5.1)	0.1	0.2
AVR					
Mean (CI 95%)	1	0.89 (0.89; 0.90)	0.88 (0.86; 0.89)	0.01	0.2
Mean (CI 95%)	2	0.88 (0.87; 0.89)	0.89 (0.88; 0.90)	0.2	0.2
CRAE (µm)					
Mean (CI 95%)	1	205.9 (204.3; 207.6)	204.9 (202.0; 207.9)	0.6	0.1
Mean (CI 95%)	2	206.1 (204.3; 207.9)	204.5 (201.0; 208.0)	0.2	0.1
CRVE (µm)					
Mean (CI 95%)	1	231.1 (229.5; 232.6)	234.3 (231.5; 237.0)	0.06	0.2
Mean (CI 95%)	2	231.8 (230.1; 233.6)	232.5 (229.3; 235.8)	0.7	0.05
Physical activity (min/day)					
Mean (CI 95%)	1	57 (52; 62)	64 (55; 73)	0.2	0.2
Mean (CI 95%)	2	57 (51; 62)	63 (52; 73)	0.4	0.1
Playing indoor (min/day)					
Mean (CI 95%)	1	64 (59; 69)	62 (52; 71)	0.7	0.05
Mean (CI 95%)	2	64 (59; 70)	62 (51; 73)	0.7	0.04
Playing outdoor (min/day)					
Mean (CI 95%)	1	80 (74; 85)	65 (55; 75)	0.02	0.3
Mean (CI 95%)	2	79 (73; 85)	59 (48; 71)	0.005	0.4
Sports club participation (in %)					
Mean (CI 95%)	1	62 (56; 68)	43 (33; 54)	0.02	0.4
Mean (CI 95%)	2	60 (54; 67)	49 (37; 61)	0.1	0.2
Sports club participation (min/week)					
Mean (CI 95%)	1	75 (63; 87)	61 (40; 83)	0.3	0.1
Mean (CI 95%)	2	69 (57; 81)	74 (51; 97)	0.7	0.05
Screen time (min/day)					
Mean (CI 95%)	1	38 (33; 43)	79 (70; 88)	<0.001	1.0
Mean (CI 95%)	2	42 (36; 47)	70 (60; 81)	<0.001	0.6

Note: Model 1: adjusted for age, sex and BMI; model 2: model 1 plus parental education level and household income: *both parents from Eastern or Southern European countries, Africa, Asia, Central or South America, or less developed countries; **only adjusted for sex and age; †effect size for the difference between the the low and the high group.

(Huynh et al., 2014). These findings, however, were alleviated when adjusted for parental education and migration status. As there were only small to negligible associations among retinal microcirculation and body composition, physical fitness as well as physical activity, the responsible mechanism for this observation remains speculative. The present study is the first to analyse the association between socio-economic factors and retinal vessel diameters as a risk factor for cardiovascular health in children.

Migrant background has the biggest influence on the anthropometrics. Twenty-one per cent of the children with migrant background were overweight, whereas only 7% of the children without migrant background were overweight. The numbers for obesity are more discrepant. While 10% of the obese children have a migrant background, only 1% of the non-migrant children are obese. Most studies on socio-economic factors and adiposity in childhood do not specify the ethnicity of the study sample. Studies with children that were stratified by ethnicities showed no association between socio-economic factors and adiposity (Shrewsbury & Wardle, 2008). Therefore, we assume that ethnicity or migrant background is more strongly correlated with BMI and body fat in children than socio-economic factors.

Migrant children show a lower performance in the cardiovascular fitness test than their non-migrant peers. This could be explained by the fact that migrant children are more

Table 5. Pearson correlations (*r*) matrix.

Parameter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. BMI (kg/m^2)	1	0.80	−0.33	0.14	−0.10	−0.15	−0.07	−0.06	−0.10	−0.1	−0.06	−0.06	−0.12	−0.10	−0.11	−0.11	0.19
2. Body fat (%)		1	−0.42	0.31	−0.18	−0.12	−0.05	−0.07	−0.08	−0.10	−0.03	−0.08	−0.13	−0.09	−0.10	−0.12	0.20
3. 20 m shuttle run (stages)			1	−0.56	0.48	0.29	0.12	0.03	−0.09	−0.5	−0.16	0.11	−0.01	0.06	0.21	0.24	−0.22
4. 20 m sprint (s)				1	−0.53	−0.36	−0.13	−0.02	0.08	0.16	0.11	−0.03	−0.06	−0.04	−0.17	−0.21	−0.01
5. Jumping sidewards (sum of jumps)					1	0.47	0.20	0.07	−0.1	−0.09	−0.10	0.02	−0.05	0.01	0.11	0.18	−0.04
6. Balancing backwards (sum of steps)						1	0.26	0.01	0.06	0.04	−0.01	−0.07	0.05	<-0.01	−0.03	0.01	−0.04
7. Spinal flexibility (°)							1	−0.07	−0.06	−0.07	−0.02	−0.10	−0.04	−0.06	−0.04	0.01	−0.01
8. Difference in spinal inclination (°)								1	−0.01	−0.04	−0.03	0.02	−0.04	0.09	0.07	0.04	−0.07
9. AVR									1	0.62	−0.28	−0.03	0.02	0.03	0.05	0.06	−0.08
10. CRAE (μm)										1	0.58	−0.01	−0.07	0.04	0.01	0.01	−0.03
11. CRVE (μm)											1	0.01	−0.1	0.02	−0.05	−0.05	0.05
12. Physical activity (min/day)												1	0.15	0.32	0.16	0.18	0.07
13. Indoor activity (min/day)													1	0.31	−0.03	−0.06	0.06
14. Outdoor activity (min/day)														1	0.12	0.04	0.01
15. Sports club participation (in %)															1	0.61	−0.16
16. Sports club participation (min/week)																1	−0.08
17. Screen time (min/day)																	1

overweight or obese, which has a negative influence on the shuttle run performance (Olds & Dollman, 2004). We also observed moderate correlations between shuttle run performance and BMI as well as body fat percentage, respectively. Another explanation could be that in our sample, children with a migrant background spent less time playing outdoor than non-migrant children. A study in adolescents has shown that youth who reported to spend more of their after-school time playing outdoors have better cardiovascular fitness than those who reported no time outdoors (Schaefer et al., 2014). However, the correlations between outdoor activity and fitness were negligible. Screen time was also associated with the migration status of the children. In addition, there were small correlations between screen time and body composition and aerobic fitness, respectively. Similar findings were presented in the review of Hoyos Cillero and Jago, who reported that ethnicity is correlated with screen time (Hoyos Cillero & Jago, 2010). Physical activity does not differ between groups of parental education, household income or migrant background. This is in line with an Australian study with 2–16-year-old children (Cameron et al., 2012). It remains to be stated that objective measurements of physical activity, such as accelerometry, could potentially lead to relevant correlations with these parameters in the future.

With regard to potential mechanisms for the obtained findings, psychological issues should be taken into account. For instance, there is evidence that lower socio-economic status is associated with greater stress (Pinderhughes, Dodge, Bates, Pettit, & Zelli, 2000). The experience of stress may impair the effort of an individual to become physically active and, thus, may support sedentary behaviours (Stults-Kolehmainen & Sinha, 2014). In consequence, this may lead to low fitness levels and poor health. On the basis of the obtained cross-sectional data, however, we cannot definitely conclude on this and, particularly on a causal effect of physical activity on physical fitness and health parameters.

The strength of this study was the objective measurement of physical fitness in a large sample of children of the same age. But since participation was voluntary, selection bias may have occurred. Only 24% of the study sample had a migrant background. But in 2013, 34% of the inhabitants of Basel-Stadt were migrants (Statistisches Amt Basel-Stadt, 2013). Although the study information was translated in seven foreign languages, the language barrier may have been the reason why less children with migrant background took part in the study. A general limitation in this regard can be seen in the low absolute number of children in the migrant group, which might have impeded to find existing differences between groups. Proxy-reported questionnaire may also produce recall bias. Further, the cause of the associations cannot be determined because of the cross-sectional design of the study. From a statistical perspective, it has to be mentioned that the socio-economic factors are correlated and, thus the ANCOVA model 2 including two of these factors might be over-adjusted, thereby biasing the true associations towards zero. Otherwise, model 1 does not take any such correlation into account and, hence, the relevance of one socio-economic factor relative to the others cannot be estimated by model 1.

Conclusion

In an urban Swiss environment such as Basel-Stadt, low parental education is negatively associated with cardiovascular fitness and postural control and is positively associated with screen time. Children with a high household income perform better in motor coordination tasks, such as jumping sidewards and balancing backwards and spend more time per week in organised sport than children with a low household income. Children with a migrant background show a higher BMI and higher per cent of body fat than children with a non-migrant background. Children with a migrant background performed worse in the 20 m shuttle run test, spent less time playing outdoors but more time in front of the screen than non-migrant children. Associations of parental education, household income and migrant background with retinal microvascular health and spinal posture were less pronounced in children of this age group. Future school-based intervention programmes may need to aim more specifically at minimising the socio-economic and ethnical discrepancies early in life.

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Chapter 9 **Synthesis, Discussion and Perspectives**

The following section summarizes the main results of the dissertation based on the addressed aims in Chapter 2. In a general discussion results of the study will be outlined and strengths and limitations of the study will be discussed. Closing, future perspectives with research gaps that may be focused on will be proposed.

9.1 Summary of the Main Results

Aim 1: To examine the association between retinal vessel diameters, body mass index, waist circumference, percentage body fat, waist to height ratio and blood pressure categories in young Caucasian children.

Aim 2: To assess the association of the 20 m shuttle run performance with retinal vessel diameters in young children. Furthermore on an explorative basis, we aimed to examine the association of additional physical fitness parameters with retinal microvascular health. Besides, subjective reporting of physical activity behaviour should be compared to previous findings in young school children.

In 391 first-graders physical fitness tests, anthropometric measurements as well as retinal vessel analysis were conducted. Proxy-reported PA questionnaires were completed by the parents. Compared to the studies that conducted analysis of anthropometrics and retinal vessel diameters in 6 to 8 year old children so far [44-46, 92], we could not find any associations between BMI and retinal vessel diameters. In our study blood pressure, in particular diastolic blood pressure is suggested to influence retinal vessels the most. A high blood pressure was negatively associated with microvascular health. We could also show that a high blood pressure, even on the pre-hypertensive level, was associated with retinal arteriolar narrowing in children.

Regarding physical fitness and retinal vessel diameters, we found that a good 20 m shuttle run performance was associated with narrower retinal venular diameters and a higher AVR. This indicates that cardiorespiratory fitness is beneficially associated with microvascular health and a better microvascular risk profile. Indoor activity was also associated with wider retinal venular diameters. Surprisingly, a good performance in the 20 m sprint was related to narrower retinal arteriolar diameters reflecting less microvascular health. Since the additional physical fitness tests were analysed on an explorative basis, further investigation of this association is recommended.

Aim 3: To analyse the associations between anthropometrics, physical fitness, spinal flexibility and postural insufficiency, as risk factors for back pain, and back pain in 6 to 8 year old children.

The measurements of physical fitness and Spinal Mouse were conducted in 395 children of Basel-Stadt. Back pain questionnaires were filled in by the parents. No associations were found between back pain and any of the other parameters. But while a good physical fitness performance was associated with a more flexible spinal inclination and a more flexible pelvic tilt, a less flexible lumbar spine was associated with a better performance in the jumping sidewards test. Besides, the wider the waist circumference was the less flexible was the spinal inclination. The strongest determinant for postural insufficiency was a low performance in the 20 m shuttle run test. Furthermore, children with a high BMI, that were heavier, had more body fat and a wider waist circumference tended to be postural insufficient in the lumbar spine.

Aim 4: To examine associations between parental educational level, household income, migrant background and physical fitness, PA behaviour, risk factors for back pain as well as retinal microcirculation in children in an urban Swiss region.

In 351 children all measurements, including physical fitness tests, anthropometrics, retinal vessel analysis and Spinal Mouse measurements, were examined. Parental education level, household income, migrant background and PA behaviour were assessed by a proxy-reported questionnaire. In Basel-Stadt parental education level, household income and migrant background were negatively related to the physical fitness level and anthropometrics of the children. No associations were found between parental education level, household income and migrant background and spinal flexibility and cardiovascular microcirculation. But, an association was found between parental education level and postural insufficiency. While children from well-educated parents were capable to control the spinal posture for more than 30 seconds, children from less-educated parents were not. Furthermore, on the one hand sports club participation was negatively associated with parental education level and household income. On the other hand screen time was positively associated with migrant background and parental education level. Our study showed that in Basel-Stadt parental education level, household income and migrant background play an important role in the children's physical fitness, anthropometrics and PA behaviour development.

9.2 General Discussion

The aim of this dissertation was to examine associations of physical fitness, anthropometrics and health factors like cardiovascular health and back health in children. As a superior aim the survey should serve as a baseline study for public health interventions in children of Basel-Stadt. In the three following chapters, findings that could not be reported in full length in the publications will be discussed in more detail, since they raise new questions for future research.

9.2.1 Cardiovascular Health

We showed that good cardiorespiratory fitness, measured by a 20 m shuttle run test, was beneficially associated with microvascular health in 6 to 8 year old children. A recently published study about carotid intima media thickness showed similar findings in 11 to 12 year old children. They reported that the risk of increased carotid intima media thickness is higher in unfit children [112]. Therefore, we concluded that cardiorespiratory fitness is associated with a better cardiovascular health in children. Longitudinal follow-up studies are needed to track the influence of cardiorespiratory fitness into adolescence and adulthood. In addition it should be examined within an intervention study whether an improved cardiorespiratory fitness can influence the cardiovascular health of children and adolescents. Explosive strength performance as tested by the 20 m sprint test was related to arteriolar narrowing in our study, which is supposed to be a marker of increased cardiovascular risk in adults and children [44-46, 48, 113]. This unexpected finding may well be explained by the effect of isometric resistance exercise on retinal vessel diameters in adults [114]. Explosive strength performance such as lifting hand weights in healthy adults induced an acute arteriolar constriction based on the myogenic response to an increase in blood pressure. It has previously been shown that children with low handgrip strength are slower in a 20 m sprint than their stronger peers [115]. Therefore, we assume that the sprint performance in children is related to strength. Hence, a high degree of explosive strength performance seems to be associated with arteriolar narrowing at rest, even after adjusting for blood pressure. As stated above, narrow retinal arterioles are associated with an adverse influence on cardiovascular risk in adults and children. In adults, high intensity resistance training, in contrast to regular endurance training, has been shown to increase arterial stiffness in large arteries [116, 117]. However, the examination of the influence of sprint performance on retinal vessel diameter was explorative and failed to remain significant after adjusting for multiple testing. Future studies are warranted to clarify whether explosive strength exercise in children, acute or chronic, has negative effects on vascular function.

In contrast to a previous Australian study about PA behaviour and microvascular health in children [49] we found that indoor, not outdoor, activity seems to be associated with wider retinal venular diameters. These results seem to highlight the importance of indoor activities in an urban environment as Basel-Stadt. An extra half hour per day spent in indoor activity seems to positively influence the retinal microvascular profile. As mentioned above in the Australian study, *outdoor* activities were found to have a positive influence on retinal arteriolar diameter in 6 year old children. These contrary findings may be explained by the geographical disparity, with a less temperate climate and more severe winters in the middle European region [118]. In their study, Gopinath et al. also found an association between screen time and microvascular health, which was not proven in our cohort [49]. But while our population spent an average of 50 minutes/day in front of a screen, the Australian population reported an average of 1.9 hours/day. So the disparity may be explained by the difference in average screen time between the two study populations.

9.2.2 Back Health

In our study only 1% of the children reported back pain. The low prevalence may explain that we could not find any association between back pain and the other measured parameters. A recent review and meta-analysis found a prevalence of back pain in children up to 6% [54]. A follow-up study is recommended to track possible relationships between physical fitness, spinal flexibility and postural insufficiency as a child with future back pain. The longitudinal literature of back pain in children is very scarce. This may be due to the expensive, unwieldy and radiant X-ray, commonly regarded as “gold standard” for examinations of the spine.

We found that physical fitness correlated with a higher flexibility in the spinal inclination and the pelvic tilt but not in the lumbar or thoracic part of the spine. In contrast, fitter children had a less flexible lumbar spine than their peers. But, as found in athletes stiffening of the lumbar spine led to an improved stabilization of the upper body for functional movements [119]. Additionally, studies with back pain patients showed, that hypermobility of the lumbar spine led to more severe back pain [120]. Therefore, having a less flexible lumbar spine might be important for physical fit children. In the thoracic part of the spine we could not find any differences in flexibility according to anthropometrics and physical fitness of the children. It is known that the thoracic spine is anatomically built for stability [121]. Hence, a lower flexibility in children with higher physical fitness could have been expected. The fact that we could not find any differences between the groups in thoracic flexibility may be because the standardized measurement position (head/neck in a neutral position, hands on the waist) makes it difficult to achieve a full thoracic extension. Similar results have been shown in a previous study with adults [72]. We therefore conclude that it is important to discriminate between different parts of the spine to evaluate whether or not being flexible in the spine is important for back health. In this regard, in a future follow-up study a differentiation in locations of back pain (neck pain, thoracic pain or low back pain) should be realised to increase the precision of the back pain assessment.

9.2.3 Socioeconomic Status and Health

As mentioned in the introduction, the influence of the socioeconomic status on children's overweight can vary between different countries [87]. Data about the influence of socioeconomic status and physical fitness in children is very scarce. Therefore, it was important to assess these data for the first time in Basel-Stadt. We could show that in Basel-Stadt parental education, household income and nationality have an influence on children's physical fitness, anthropometrics and postural insufficiency. Children from low educated parents, of a low income household or migrants had a lower physical fitness level, were more often overweight/obese and were more postural insufficient. These findings are important for Basel-Stadt since physical fitness interventions seem to be needed especially in families with a low socioeconomic status. Based on this knowledge interventions can be planned more specifically and adapted to the respective focus. Since in Basel-Stadt income and nationality maps are drawn every year, it is possible to analyse the associations between physical fitness, anthropometrics and the socioeconomic status and a spatial analysis can be performed every year in the future based on the Sportcheck data. In addition, with a spatial analysis we can examine if green spaces, walkability to a movement friendly place, traffic speed and volume in the neighbourhood may play an important role for the physical fitness level of the children in Basel-Stadt [122]. The way to school is also important for children, especially whether or not they commute actively. It was shown that active commuting to school is associated with an increased cardiorespiratory fitness and increased daily energy expenditure in children and adolescents [123]. With the SCARPOL study as an example we already have data of children's active commuting to school in Switzerland [124]. Thereby, 75.6% of the first-graders in small towns of Switzerland commute actively to school, either by foot or by bike/kickboard/scooter. We assume that the numbers in Basel-Stadt are similar. Reasons for not active commuting in Switzerland are the distance to school and major road crossings. Therefore, distance to school should be as short as possible and safety needs to be improved for pedestrians and cyclists [124].

9.3 Strengths and Limitations

The biggest strength of our study is the implementation of the results in a public health context. Every child received all its results and a recommendation how to improve health or how to stay healthy (Appendix A & D). Besides, we could set up and examine a representative big cohort of children of Basel-Stadt with measurements that are valid and reliable and easy to use in the field. Furthermore, this cross-sectional cohort analyses will serve as the baseline study for a longitudinal cohort study including the same measurements. In addition, there are very few data on retinal vessel diameters as increasingly acknowledged early cardiovascular risk parameters in children. Retinal vessel analysis represents a promising method to assess cardiovascular risk at an early stage in order to implement prevention programs before the onset of further vascular modifications or upcoming vascular damage later in life. An additional strength of the study was the objective measurement of physical fitness in addition to proxy-reported PA assessment. It has already been shown that PA is better represented by measuring cardiorespiratory fitness than by physical activity questionnaires [125].

Hence, as a limitation of the present study the proxy reported questionnaire may cause recall bias. However, the children were too young to fill out the questionnaire themselves and the accuracy of the responding by the parents was improved because the questionnaire was imbedded in the school setting. Furthermore, since physical fitness was tested objectively the questionnaires served only as a supplement measurement. In a future study accelerometer should be used to objectively measure the children's PA level besides a PA questionnaire.

Another limitation is the cross-sectional design of the study that does not allow the examination of longitudinal and causal associations. However, since this dissertation will serve as a baseline examination and a follow-up is planned, longitudinal analyses will be possible in the future and will give extensive long-term insights in associations between physical fitness, cardiovascular health and back pain. Compared to the current population of first-graders of Basel-Stadt a selection bias in the number of migrants (our sample: 27%, Sportcheck project: 40%) and obese children (our sample: 3.4%, Sportcheck project: 5.9%) occurred. Although the parental information of the study was translated in the seven most spoken languages of Basel-Stadt, the language may have been a reason, why fewer migrants participated in the study. Besides compared to the population of the Sportcheck project also a selection bias in the physical fitness level occurred. In our sample children were significantly better in the 20 m shuttle run in both sexes, in jumping sidewards in boys and in balancing backwards in girls (each $p \leq 0.01$).

9.4 Perspectives

Within the Sportcheck physical fitness tests and measurements of height, weight and body fat will be conducted in all first-graders of the canton Basel-Stadt yearly. This dissertation provides a basis for this large cohort project. Sportcheck data sampled in the future should be used to show the secular trends of physical fitness in Basel-Stadt and serve as a basis for improving and extending physical education lessons in school and for building up further education classes for teachers in physical education. Furthermore, this dissertation sets the scientific ground for improving the *additional* physical education classes and for adapting them by evaluation of the children’s interests and, according to the results of the dissertation thesis, for implementing back therapy training and cardiorespiratory fitness training, at the best by games, in physical education lessons.

Another future aim connected with this dissertation is to conduct a follow-up study to examine the long-term effect of cardiorespiratory fitness on the cardiovascular risk profile or back health from childhood to adolescence and adulthood. Thus, the same children will be recruited again in sixth grade and all herewith conducted measurements will be examined longitudinally five year after the baseline data collection.

Based on the current data a fifth manuscript is planned, analysing associations between physical fitness and blood pressure in children. Previous studies have shown that low cardiorespiratory fitness is associated with higher systolic and diastolic blood pressure in children and adolescents aged 8-18 years [126-128]. Studies about younger children are still scarce. A European study showed that in 2 to 9 year old children low levels of PA and higher amounts of sedentary behaviour increased the risk of developing high blood pressure after two years of follow-up [129]. Furthermore and against the background that anthropometrics have an influence on blood pressure level already in young children studies about associations between physical fitness, especially cardiorespiratory fitness, and blood pressure in younger children are recommended.

Besides, in the next three years a future study with the same design is planned to increase the current sample and analyse the associations between the so far explorative physical fitness measurements, 20 m sprint, jumping sidewards and balancing backwards tests and the retinal vessel diameters. Especially, the association between the 20 m sprint and retinal vessel diameters should be analysed in more detail, since in our study the 20 m sprint test was unexpectedly related to arteriolar narrowing, a marker of increased cardiovascular risk in adults and children. In addition, the test battery will be expanded by measurements of arterial stiffness, measurements of advanced glycation end products, lung function and air pollution. The aim is to assess associations between cardiovascular health, especially of the microvasculature, lung function and air pollution in children of Basel-Stadt. It is a major public health concern to analyse interrelations between environmental determinants such as air pollution and children's health, in particular pulmonary and cardiovascular health. This holds true especially in urban areas with higher levels of ambient and traffic-related air pollution. In this regard it is of greatest interest to draw conclusions for redesigning children's ways to school in order to promote active commuting to school.

Also, the spatial analysis can be used to examine the environment of the schools and to analyse associations between the school environment and the physical fitness or overweight/obesity of the children. If the neighbourhoods with the least fit children overlap with an activity unfriendly environment in Basel-Stadt the maps may support to assure politicians of the need of activity friendly environments in those neighbourhoods. According to a recent review an important factor of the promotion of children's PA in a neighbourhood are safe ways to neighbourhood amenities [130]. This is because in young age parental safety concerns play a major role in allowing children to play outside or to actively commute. Other important factors were traffic speed and volume, residential density and proximity to recreation facilities in the neighbourhood, which correlated inversely with children's PA level [122]. Using the findings of the Sportcheck project and spatial analysis the safety of the way to school of the first-graders of Basel-Stadt can be compared with the physical fitness data in the future.

Moreover, with the help of the physical fitness and overweight/obesity maps of Basel-Stadt the neighbourhood with the least fit and most overweight children will be analysed after at least three years of data collection. Then the sample size per school will allow clustering of the data by the schools. For neighbourhoods with lack of children's physical fitness or an alarming number of overweight/obese children compared to other neighbourhoods or reference areas an evaluation of the reasons for these aspects will be performed. Based on this evaluation, an intervention program will be organised especially to increase the physical fitness of these children in the respective neighbourhood. The Cantonal Office of Sport of Basel-Stadt will be the investigator of this project in cooperation with the Department of Sport, Exercise and Health of the University of Basel.

In addition, Basel-Stadt should serve as an example to promote children's health in schools and neighbourhoods. Our vision is to implement the Sportcheck in every canton of Switzerland to promote children's physical fitness in connection with cardiovascular and back health on a Swiss wide level. Future long-term analyses of the Sportcheck data will provide the scientific basis for the efficacy of this PA related health promotion program from childhood to adulthood.

9.5 Overall Conclusion

The aim of this dissertation was to investigate associations between physical fitness and on the one hand cardiovascular health, and on the other hand back health in a cohort of Swiss first-graders. From a public health perspective, another overall aim was to assess data to enforce changes in the current physical education system of the Swiss canton Basel-Stadt. In this regard, the Sportcheck project also served and will serve as an instrument to collect scientific facts to influence political decisions concerning PA promotion in young children within the school setting and beyond regarding activity-friendly environments in Basel-Stadt and building on this in other parts of Switzerland. Generally, we could show that good physical fitness is positively associated with cardiovascular and back health in young children. In conclusion this dissertation project suggests that good cardiorespiratory fitness and an extra half an hour of indoor activity may have a positive effect on retinal vessel diameters in an urban population of 6 to 8 year olds. Furthermore, good physical fitness was associated with a higher flexibility in the spinal inclination and the pelvic tilt of the children. Contrary, fitter children had a less flexible lumbar spine than their counterparts. Besides, we found that in Basel-Stadt migrant children and children of less educated parents and a low income are less fit and less physically active than their peers. Hence, it is important to promote children's PA in the school setting, where every child can be reached. In addition, it is recommended to create activity-friendly spots in every neighbourhood of Basel-Stadt to develop an urban environment that inspires to more PA. The Sportcheck project may serve as a scientific basis for future political decisions in favour of PA promotion and PA friendly environment as important health promotion measures in early life.

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Appendix A

Example of a recommendation letter for movement promotion lessons, additional sports lesson and Talent Eye

Sportcheck – Auswertung für Muster Max / Bewegungsförderung

Klasse: 1A Schulhaus: Musterschule

Grösse: 122.0 cm
Gewicht: 23.0 kg
Body Mass Index BMI (normal, niedrig, hoch): normal

Test°	Kategorie	Ergebnis*	Bewertung°°
seitliches Springen	Kraftausdauer	9 x	+
rückwärts Balancieren	Koordination	11 Schritte	+
Sprint	Schnelligkeit	5.9 Sek.	++
Shuttle Run	Ausdauer	11 Längen	+
		Gesamtbewertung	+

° Mehr Informationen zu den einzelnen Tests auf der Rückseite oder beim Sportamt: 061 267 57 28.

°° Die „+“ zeigen in einfacher Form an, wie gut das Kind bei einer Übung abgeschnitten hat. Es werden maximal 5 "+“ vergeben. Bitte berücksichtigen Sie, dass die Leistungen der Kinder starken Schwankungen (z.B. Tagesform) unterliegen. Die Auswertung darf deshalb allgemein nicht überbewertet werden.

* fehlt ein Resultat, so konnte ihr Kind aus gesundheitlichen Gründen (vorausgehende Verletzung), wegen rutschigen Strümpfen beim Balancieren oder Motivationsgründen an diesem Test nicht das Maximum erzielen.

+++++ : hervorragender Entwicklungsstand
++++ : überdurchschnittlicher Entwicklungsstand
+++ : durchschnittlicher Entwicklungsstand
++ : in der Entwicklung zu fördern
+ : in der Entwicklung umfassend und gezielt zu fördern

Angebote freiwilliger Schulsport

Für Ihr Kind empfehlen wir aufgrund der Testresultate folgendes Angebot/folgende Angebote:

Angebot	Empfehlung
Bewegungsförderung Hier werden Schülerinnen und Schüler mit einem motorischen oder körperlichen Förderbedarf gezielt individuell gefördert.	empfohlen
Sportförderung Ein breites, polysportives Angebot, welches allen Schülerinnen und Schülern offen steht.	(empfohlen)
Talentförderung Bewegungsbegabte und interessierte Schülerinnen und Schüler haben die Möglichkeit, sich unter fachkundiger Anleitung weiter zu entwickeln. Die Kinder werden von der kantonalen Leistungssportförderung begleitet und behutsam an den Leistungssport herangeführt.	------

Weitere Informationen zum freiwilligen Schulsport unter www.sport.bs.ch, *Link* Freiwilliger Schulsport.

Sportcheck – Auswertung für Muster Max / Sportförderung

Klasse: 1A Schulhaus: Musterschule

Grösse: 125. 0 cm
Gewicht: 24.30 kg
Body Mass Index BMI (normal, niedrig, hoch): normal

Test°	Kategorie	Ergebnis*	Bewertung°°
seitliches Springen	Kraftausdauer	58 x	++++
rückwärts Balancieren	Koordination	18 Schritte	+
Sprint	Schnelligkeit	4.9 Sek.	+++
Shuttle Run	Ausdauer	35 Längen	+++
		Gesamtbewertung	+++

° Mehr Informationen zu den einzelnen Tests auf der Rückseite oder beim Sportamt: 061 267 57 28.

°° Die „+“ zeigen in einfacher Form an, wie gut das Kind bei einer Übung abgeschnitten hat. Es werden maximal 5 "+“ vergeben. Bitte berücksichtigen Sie, dass die Leistungen der Kinder starken Schwankungen (z.B. Tagesform) unterliegen. Die Auswertung darf deshalb allgemein nicht überbewertet werden.

* fehlt ein Resultat, so konnte ihr Kind aus gesundheitlichen Gründen (vorausgehende Verletzung), wegen rutschigen Strümpfen beim Balancieren oder Motivationsgründen an diesem Test nicht das Maximum erzielen.

+++++ : hervorragender Entwicklungsstand
++++ : überdurchschnittlicher Entwicklungsstand
+++ : durchschnittlicher Entwicklungsstand
++ : in der Entwicklung zu fördern
+ : in der Entwicklung umfassend und gezielt zu fördern

Angebote freiwilliger Schulsport

Für Ihr Kind empfehlen wir aufgrund der Testresultate folgendes Angebot/folgende Angebote:

Angebot	Empfehlung
Bewegungsförderung Hier werden Schülerinnen und Schüler mit einem motorischen oder körperlichen Förderbedarf gezielt individuell gefördert.	------
Sportförderung Ein breites, polysportives Angebot, welches allen Schülerinnen und Schülern offen steht.	empfohlen
Talentförderung Bewegungsbegabte und interessierte Schülerinnen und Schüler haben die Möglichkeit, sich unter fachkundiger Anleitung weiter zu entwickeln. Die Kinder werden von der kantonalen Leistungssportförderung begleitet und behutsam an den Leistungssport herangeführt.	------

Weitere Informationen zum freiwilligen Schulsport unter www.sport.bs.ch, *Link* Freiwilliger Schulsport.

Sportcheck – Auswertung für Muster Max / Talent Eye

Klasse: 1A Schulhaus: Musterschule

Grösse: 121. 0 cm
Gewicht: 22.50 kg
Body Mass Index BMI (normal, niedrig, hoch): normal

Test°	Kategorie	Ergebnis*	Bewertung°°
seitliches Springen	Kraftausdauer	58 x	++++
rückwärts Balancieren	Koordination	72 Schritte	+++++
Sprint	Schnelligkeit	4.1 Sek.	++++
Shuttle Run	Ausdauer	60 Längen	++++
		Gesamtbewertung	+++++

° Mehr Informationen zu den einzelnen Tests auf der Rückseite oder beim Sportamt: 061 267 57 28.

°° Die „+“ zeigen in einfacher Form an, wie gut das Kind bei einer Übung abgeschnitten hat. Es werden maximal 5 "+“ vergeben. Bitte berücksichtigen Sie, dass die Leistungen der Kinder starken Schwankungen (z.B. Tagesform) unterliegen. Die Auswertung darf deshalb allgemein nicht überbewertet werden.

* fehlt ein Resultat, so konnte ihr Kind aus gesundheitlichen Gründen (vorausgehende Verletzung), wegen rutschigen Strümpfen beim Balancieren oder Motivationsgründen an diesem Test nicht das Maximum erzielen.

+++++ : hervorragender Entwicklungsstand
++++ : überdurchschnittlicher Entwicklungsstand
+++ : durchschnittlicher Entwicklungsstand
++ : in der Entwicklung zu fördern
+ : in der Entwicklung umfassend und gezielt zu fördern

Angebote freiwilliger Schulsport

Für Ihr Kind empfehlen wir aufgrund der Testresultate folgendes Angebot/folgende Angebote:

Angebot	Empfehlung
Bewegungsförderung Hier werden Schülerinnen und Schüler mit einem motorischen oder körperlichen Förderbedarf gezielt individuell gefördert.	------
Sportförderung Ein breites, polysportives Angebot, welches allen Schülerinnen und Schülern offen steht.	(empfohlen)
Talentförderung Bewegungsbegabte und interessierte Schülerinnen und Schüler haben die Möglichkeit, sich unter fachkundiger Anleitung weiter zu entwickeln. Die Kinder werden von der kantonalen Leistungssportförderung begleitet und behutsam an den Leistungssport herangeführt.	empfohlen

Weitere Informationen zum freiwilligen Schulsport unter www.sport.bs.ch, *Link* Freiwilliger Schulsport.

Detailbeschrieb der sportmotorischen Tests

Seitliches Springen

Bedeutsamkeit: Koordination und Kraftausdauer

Durchführung:
Innerhalb von 15 Sekunden mit beiden Beinen so schnell wie möglich seitlich über eine Holzleiste hin- und herspringen.

20 Meter Sprint

Bedeutsamkeit: Schnelligkeit

Durchführung:
Jedes Kind durchläuft einzeln, aus dem Hochstart möglichst schnell die Laufstrecke.

Rückwärts Balancieren:

Bedeutsamkeit: Koordination

Durchführung:
Jedes Kind balanciert pro Balken (6cm. 4.5 cm, 3cm Breite) 3 Mal rückwärts. Gezählt werden die Anzahl Schritte bis ein Fuss den Boden berührt (jedoch max. 8 Schritte).

Shuttle Run

Bedeutsamkeit: Ausdauer

Durchführung:
Die Kinder müssen zwischen zwei Linien hin und her laufen. Die Laufgeschwindigkeit wird durch Intervalle zwischen zwei Tonsignalen angegeben.

Appendix B

Recommendation for the teachers

Auswertung Klasse

Schulkreis a Schulhaus: x Klasse: y Lehrperson: xy Anzahl Schüler: 18

Name	Vorname	BMI	Shuttle Run	Sprint	rückwärts Balancieren	seitl. Hin- und Herspringen	Gesamtbewertung	Sport-förderung	Bewegungs-förderung	Talent-förderung
x	y	normal	+++++	+++++	++++	+++++	++++	empfohlen		empfohlen
x	y	normal	+	++++	+++++	++++	+++	empfohlen		
x	y	hoch	+	+++	++	++	++	empfohlen	empfohlen	
x	y	hoch	+	+++	++	++	++	empfohlen	empfohlen	
x	y	normal	++	+++++	++	+++	+++	empfohlen		
x	y	normal	++	+++	+++	+++	+++	empfohlen		
x	y	hoch	+	++	++	+++	++	empfohlen	empfohlen	
x	y	normal	+	+++	+++	+++	+++	empfohlen		
x	y	normal	++	+++++	+++	++++	+++	empfohlen		
x	y	normal	++++	+++++	+++++	++++	++++	empfohlen		empfohlen
x	y	hoch	+	+	+	++	+	empfohlen	empfohlen	
x	y	normal	++	++++	+++	+++++	+++	empfohlen		
x	y	normal	+	+++	++	++++	+++	empfohlen		
x	y	normal	+	+++++	+++	++	+++	empfohlen		
x	y	hoch	++	+++	+++	+++	+++	empfohlen		
x	y	normal	+	++++	+++++	+++++	++++	empfohlen		
x	y	normal	+	+++	+++	+++++	+++	empfohlen		
x	y	hoch	+	+++	++	++	++	empfohlen	empfohlen	
Durchschnitt Klasse		normal	++	++++	+++	++++	+++			

* Die „+“ zeigen in einfacher Form an, wie gut das Kind bei einer Übung abgeschnitten hat. Es werden maximal 5 "+“ vergeben. Bitte berücksichtigen Sie, dass die Leistungen der Kinder starken Schwankungen (z.B. Tagesform) unterliegen. Die Auswertung darf deshalb allgemein nicht überbewertet werden.

+++++ : hervorragender Entwicklungsstand
++++ : überdurchschnittlicher Entwicklungsstand
+++ : durchschnittlicher Entwicklungsstand
++ : im Sportunterricht zu fördern
+ : unbedingt und gezielt im Sportunterricht zu fördern

Linksammlung für den Sportunterricht unter www.sport.bs.ch, *Link Sport in der Schule, Freiwilliger Schulsport, Sportcheck.*

Appendix C

4 x 4 of the Sportcheck: a booklet for teachers with physical exercises to improve the specific fitness parameters measured in the Sportcheck

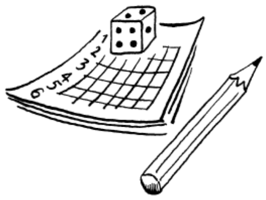
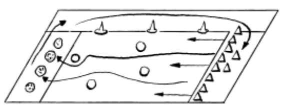
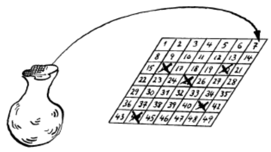
4 x 4 des Sportchecks

Rückwärts balancieren

Einbeinkünstler[1] 	Auf einem Bein stehen und versuchen, ganz unterschiedliche Positionen einzunehmen. Nach rund einer Minute das Bein wechseln. **Erschweren:** • Aufgaben auf instabiler Unterlage ausführen, z.B. Wackelkissen, dicke Matte, etc. **Variationen:** • Das freie Bein und den Körper möglichst locker schwingen/kreisen. • Mit den Händen einen Gegenstand um den Körper führen. • Aufgaben mit geschlossen Augen durchführen. • Zu zweit Gegenstände zuwerfen. **Material:** (Gegenstände zum Zuwerfen)
Achtung Krokodil[2] 	Verschiedene Gleichgewichtsstationen und Geräte werden aufgestellt und miteinander verbunden, z.B. Langbänke, Seile, Teppichfliessen, Reifen, Ringe, etc. Die Kinder balancieren über den Parcours ohne den Boden zu berühren. **Variationen:** • Die Kinder müssen Gegenstände von A nach B transportieren. • Mit geschlossenen Augen und einem Blindenhund (Partner/in) als Helfer. **Material:** Langbänke, Seile, Reifen, Ringe, etc.
Hochseilkünstler/in[3] 	Die Schüler/innen balancieren über die schmale Seite der Langbank. **Vereinfachen:** • Übungen auf einer Linie auf dem Boden durchführen. **Erschweren:** • Langbank auf zwei Schwedenkasten fixieren. • Langbank auf einer instabilen Unterlage platzieren, z.B. auf Niedersprungmatten. **Variationen:** • Vorwärts, rückwärts, seitwärts laufen. • Auf allen Vieren gehen. • Über Hindernisse steigen. • Zu zweit mit Kreuzen in der Mitte. • Während dem Laufen einen Ball hochwerfen. • Zu zweit einen Ball zuwerfen. **Material:** Langbänke, (Schwedenkasten, Niedersprungmatten)
Gleichgewichtcircuit 	Verschiedene Posten mit Balancematerial in der Halle aufstellen. Die Schüler/innen haben in Zweier- oder Vierergruppen jeweils 3 bis 5 Minuten Zeit einen Posten auszuprobieren, danach wird gewechselt. **Vereinfachen:** Partner/in hilft das Gleichgewicht zu halten. **Material:** Pedalos**,** Moonhopper**,** Balance Boards, Kreisel**,** Medizinbälle, Langbänke**,** Gymnastikbälle**,** etc.

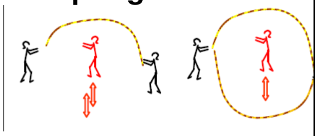
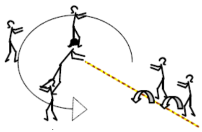
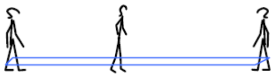
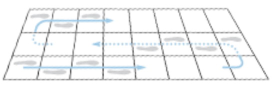
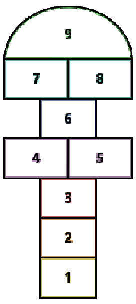
[1] Quelle: J+S Kids mobile Praxis 33 (Nr. 5, 2007)
[2] http://www.mobilesport.ch/2011/06/13/js-kids-balancieren-achtung-krokodil
[3] http://www.mobilesport.ch/2011/06/13/js-kids-balancieren-seiltaenzerin

Shuttle Run

Taschenrechner 	Die Klasse wird in 4-5er Gruppen eingeteilt. Jede Gruppe erhält einen Würfel, ein Blatt Papier und einen Stift. Das erste Kind würfelt, schreibt die Zahl auf das Papier und läuft anschliessend die Anzahl gewürfelter Runden. Sobald das erste Kind seine Zahl aufgeschrieben hat, darf das nächste würfeln und seine Zahl addieren. Welche Gruppe hat zuerst 100 Punkte erreicht? **Vereinfachen:** Falls das Zusammenrechnen zu schwierig ist, Blätter mit vorgedruckten Zahlen und eine Spielfigur bereitstellen. **Variation:** • Jede Augenzahl hat eine andere Form des Laufens zur Folge, z.B. seitwärts, rückwärts, mit Ball, Hopserlauf, etc. **Material:** Würfel, Bleistifte, Papier, eventuell Zahlenblatt, Spielfigur
Schmuggler[4] 	In der Mittelzone der Halle stehen 3 bis 4 Wächter, je nach Hallen- und Klassengrösse. Das Gold (Spielbändeli, Klammern, Gummibändeli, etc.) liegt an einem Hallenende. Die Kinder versuchen das Gold in die eigene Zone zu bringen, wobei immer nur ein Goldstück transportiert werden darf. Wer von den Wächtern berührt wird, muss auf einem Bein hüpfend das Gold zurückbringen, ausserhalb des Spielfeldes an den Start laufen und neu beginnen. Welches Team hat am Ende am meisten Gold gesammelt? **Material:** Spielbändeli, Gummibändeli, Markierungskegel
Lotto[5] 	Es werden vier Teams gebildet. Alle Kinder laufen gleichzeitig. Wer zur anderen Hallenseite und zurück gelaufen ist, entnimmt dem Gruppensack einen Lottostein. Passt der Stein zu einer Lottokarte, wird er hingelegt; wenn nicht, kommt er wieder in den Sack zurück. Welches Team hat nach 6 Minuten am meisten Lottosteine auf den Karten? Welches Team hat die meisten vollständigen Reihen? **Material:** Ein Lotto Set pro Gruppe
Runden vs. Treffer[6] 	2-4 Gruppen. Gruppe A versucht möglichst rasch eine Wurfaufgabe zu erfüllen. Die anderen Gruppen versuchen währenddessen möglichst viele Runden oder Längen zu laufen. Pro Runde erhalten alle ein Gummibändeli. Welche Wurfgruppe lässt am wenigsten Läufe zu? Oder welche Gruppen holen zusammen am meisten Läufe? **Mögliche Aufgabenstellungen:** • Mit Tennisbällen 10 Gegenstände ab einem Bänkli schiessen. • 10 Treffer in den Basketballkorb. • 30 Badmintonshuttle oder Tennisbälle in ein Kastenoberteil werfen, etc. **Material:** Gummibändeli, Tennisbälle oder Badmintonshuttle, Markierungskegel

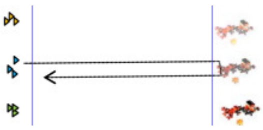
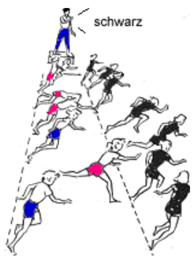
[4] Lehrmittel Sporterziehung. Band 3, Broschüre 4 (Laufen, Springen, Werfen). S. 13.
[5] J&S Kids. Top-Spiele für den Sportunterricht. S. 36.
[6] http://www.mobilesport.ch/2011/06/27/erwachsenensport-spielerische-ausdauer-lebende-stoppuhr

Seitwärts Hin und Herhüpfen

Seilspringen[7]  	Springen mit dem Langseil • Alleine • In Gruppen • Mit Zusatzaufgaben **Vereinfachen:** • vw / sw über ein Seil springen, welches auf dem Boden liegt • Leiter schwingt Seil um sich herum. Die Kinder springen über das Seil. Wer springt am längsten ohne Fehler? Evtl. Zusatzaufgabe bei Fehler (alleiniges Seilspringen) Variante: gegen das Seil im Kreis rennen (und springen) **Erschweren:** • Seil am einen Ende an Sprossenwand befestigen und der Partner schwingt auf der anderen Seite • Alleine Seilspringen (Normal, Einbeinig, Hampelmann, Galopp, etc.) **Material:** Seile, Langseile, Sprossenwand
Gummitwist[8]  Link für Beispiele: http://www.labbe.de/zzzebra/index.asp?themaid=361&titelid=880	• Diverse Sprungkombinationen zur Auswahl stellen • Kinder zeigen sich gegenseitig Sprungkombinationen vor und die anderen machen sie nach **Variationen:** • Sprunggarten aufbauen: Gummitwists zwischen Bäumen oder Malstäben auf Fuss- oder Kniehöhe kreuz und quer gespannt werden. Die Kinder springen nun ein- und beidbeinig wie Kängurus durch den Sprunggarten. • In Zweiergruppen: Die Kinder springen einander verschiedene Wege vor. **Material:** Gummitwists, ausgedruckte Sprungkombinationen
Koordinationsgitter[9] 	• Selber vor- und nachmachen • Wie bestimmte Tiere hüpfen • Von beiden Seiten starten und kreuzen • Nie zweimal in der gleichen Art hüpfen • Ball zwischen den Beinen einklemmen • Muster auf Aufgabenblatt vorgeben und selber erfinden **Material:** Koordinationsgitter, Linien, Klebeband oder Kreide
Reifen hüpfen[10]  	Reifen werden auf einer Linie einzeln und nebeneinander angeordnet. Zum Beispiel wie bei Himmel und Hölle. • Nur mit einem Fuss in einen Reifen hüpfen • Rückwärts / Seitwärts hüpfen **Vereinfachen:** • Immer mit beiden Füssen in einen Reifen hüpfen **Erschweren:** • Arme beim Himmel und Hölle dazunehmen: Beim einbeinigen Durchhüpfen der Reifen den gleichen Arm ausstrecken. Muss mit beiden Beinen gleichzeitig in je einen Ring gehüpft werden, dann beide Arme ausstrecken. **Material:** Reifen

[7] Quelle: http://www.mobilesport.ch/wp-content/uploads/2012/02/Leichtathletik_4_d.pdf abgerufen am 2.4.14
[8] Quelle: http://www.mobilesport.ch/wp-content/uploads/2012/02/Leichtathletik_19_d.pdf, abgerufen am 2.4.14
[9] Quelle: http://www.mobilesport.ch/wp-content/uploads/2012/02/SchnelleBeine.gif abgerufen am 2.4.14
[10] Quelle: www.wikipedia.ch, abgerufen am 29.1.2014

20m Sprint

Stafetten[11 12]  	• Umkehrstafetten (Start und Ziel am gleichen Ort) • Pendelstafette (Gruppe ist aufgeteilt, man pendelt hin und her) **Variation:** • Jasskartenstafette: Ein Jasskartenset liegt verdeckt beim Wendepunkt. Vier Teams. Jedes Team erhält eine Farbe. Welches Team hat zuerst alle 9 Karten gefunden? • Puzzle-Stafette: Jeweils eine Person holt ein Puzzleteil auf der gegenüberliegenden Hallenseite, sprintet zurück und klatscht mit der nächsten Person in der Reihe ab. Die anderen basteln das Puzzle zusammen. Welche Gruppe hat das Puzzle zuerst fertig? **Material:** Malstäbe, (Puzzle, Jasskarten)
Matten / Reifenfangis[13] 	3-4 Fänger sind mit einem Spielband gekennzeichnet. Auf der Matte ist man sicher. Stellt sich ein anderes Kind darauf, muss man die Matte verlassen und darf nicht auf dieselbe Matte zurück. Wer gefangen wird erhält das Spielband vom Fänger. **Vereinfachen:** • Weniger Fänger bzw. mehr Matten **Erschweren:** • Mehr Fänger bzw. weniger Matten **Material:** Matten oder Reifen, Bändeli für Fänger
Mathematik Fangis[14] 	Aufteilen in 2 Gruppen. Zwei Schüler legen sich in der Hallenmitte entgegengesetzt auf den Boden (z.B. Sohle an Sohle auf dem Bauch oder Rücken). Die Lehrperson stellt eine Matheaufgabe. Bei einer ungeraden Zahl rennen alle Kinder von Gruppe A weg. Bei einer geraden Zahl die Kinder der Gruppe B und versuchen die Sicherheitszone zu erreichen. Die Kinder der anderen Gruppe versuchen die Flüchtenden zu fangen, bevor sie sich in Sicherheit gebracht haben. Wer sich retten kann oder den Partner vor der Ziellinie berührt, erhält einen Punkt. **Variation:** • Geschichte erzählen und Gruppe A hört auf das Wort Tag (weiss). Gruppe B auf das Wort Nacht (schwarz). • Verschiedene Startpositionen anwenden (Liegend, Stehend, Füsse zueinander, Kopf zueinander) **Material:** Mathematikaufgaben, (Geschichte)
Pantominen-Sprint[11] 	Mithilfe von Gegensatzerfahrungen eine Vorstellung von der Technik des Schnelllaufens bekommen. Eine Hallenlänge lang: • rennen wie ein Elefant • rennen wie eine Gazelle / Reh • rennen wie ein Riese • rennen wie ein Zwerg • rennen mit Händen in den Hosentaschen • rennen mit grosser Armbewegung • rennen mit Riesenschritten • rennen mit Mäuseschritten Nachfragen, mit welcher Metapher sie am schnellsten rennen konnten, Bild einprägen.[11] **Material:** keines

[11] http://www.mobilesport.ch/wp-content/uploads/2011/02/LA_2_Stafetten_d.pdf abgerufen am 7.4.14
[12] http://www.mobilesport.ch/wp-content/uploads/2011/04/LA_1_Schnell-laufen_d_kor.pdf abgerufen am 7.4.14
[13] http://www.mobilesport.ch/wp-content/uploads/2011/02/LA_3_Laufen-uber-Hindernisse_d.pdf abgerufen am 7.4.14
[14] http://www.sportpaedagogik-online.de/leicht/laufspiele1.html abgerufen am 30.4.14

Appendix D

Examples of letters for the parents with the results of the additional voluntary tests of the Sportcheck with and without abnormalities

UNIVERSITÄT BASEL

Departement für Sport,
Bewegung und Gesundheit

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Provisorisches Beispiel Auswertungsschreiben

KEINE Auffälligkeiten

Familie x

x

x

Basel, 20. Mai 2014

Untersuchungsergebnisse Sportcheck+

Liebe Familie x

Wir haben im Rahmen des Gesundheitsprojekts „Sportcheck+“ im Frühjahr 2014 einen Gesundheitscheck in der Schule durchgeführt, der folgende Ergebnisse für **x** erbrachte:

Körperfett:
Der Bauchumfang beträgt 53 cm, der Körperfettwert beträgt 15.0%. Dieser Wert ist für sein/ihr Alter normal. Wir empfehlen Ihnen Sportförderung. Infos finden sie auf www.sport.bs.ch unter dem Link: freiwilliger Schulsport.

Blutdruck:
Der Blutdruck von x beträgt 107.5/67.5 mmHg und ist somit normal.
Erhöhte Blutdruckwerte könnten auch situativ entstanden sein, weil ihr Kind beim Test nervös war/oder wegen anderen Umständen (wie z.B. Nahrungsaufnahme direkt vor dem Test, Angst,..). Während der Wachstumsphase sind Kinder auch häufig von zu tiefen Blutdruckwerten betroffen.

Gefässe (mittels statischer Gefässanalyse):
Die Befunde zeigen keine Auffälligkeiten.

Fehlen an einer Stelle die Resultate, dann wurde diese Messung bei Ihrem Kind nicht durchgeführt.

Alle Werte wurden altersgerecht ausgewertet.

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Wirbelsäulenanalyse:
Die Laborbefunde zeigen keine Auffälligkeiten.

Bitte beachten Sie, dass Bewegung für Ihr Kind in jedem Fall wichtig ist. Ihr Kind sollte sich pro Tag bis zu 90 Minuten bewegen. Dies kann erreicht werden, wenn das Kind zu Fuss zur Schule geht, sich viel Draussen aufhält, im Haus genügend Platz für Bewegung zur Verfügung steht und freiwillige Schulsportangebote oder Vereinsangebote wahrgenommen werden.

Falls Sie noch weitere Informationen benötigen, stehen wir Ihnen gerne zur Verfügung. Bitte wenden Sie sich an Katharina Imhof, katharina.imhof@unibas.ch, 061 377 87 36.

Mit freundlichen Grüssen

PD Dr. phil. nat. Lukas Zahner

Beilage: Testbeschriebe

UNIVERSITÄT BASEL

Departement für Sport,
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Provisorisches Beispiel Auswertungsschreiben jeder Befund „negativ“

Familie x

x

x

Basel, 20. Mai 2014

Untersuchungsergebnisse Sportcheck+

Liebe Familie x

Wir haben im Rahmen des Gesundheitsprojekts „Sportcheck+“ im Frühjahr 2014 einen Gesundheitscheck in der Schule durchgeführt, der folgende Ergebnisse für **x** erbrachte:

Körperfett:
Der Bauchumfang beträgt 63.75 cm, der Körperfettwert beträgt 31.0%. Dieser Wert ist für sein/ihr Alter zu hoch. Wir empfehlen Ihnen Bewegungsförderung. Infos finden sie auf www.sport.bs.ch unter dem Link: freiwilliger Schulsport, Angebot: 'rundum bewegt'.

Blutdruck:
Der Blutdruck von x beträgt 112/66.5 mmHg und ist somit hoch-normal.
Erhöhte Blutdruckwerte könnten auch situativ entstanden sein, weil ihr Kind beim Test nervös war/oder wegen anderen Umständen (wie z.B. Nahrungsaufnahme direkt vor dem Test, Angst,..). Während der Wachstumsphase sind Kinder auch häufig von zu tiefen Blutdruckwerten betroffen.

Gefässe (mittels statischer Gefässanalyse):
Die Befunde zeigen Abweichungen von der Norm. Die Bilder vom Augenhintergrund deuten auf ein vergleichsweise kleines arterio-venöses Verhältnis hin (arterio-venöses Verhältnis (AVR: 0.78). Wir empfehlen regelmässige Kontrolluntersuchungen (zum Beispiel alle zwei Jahr) durch den Kinderarzt zur Beurteilung der Herz-Kreislauf- Gesundheit bis ins Erwachsenenalter, eine

Fehlen an einer Stelle die Resultate, dann wurde diese Messung bei Ihrem Kind nicht durchgeführt.

Alle Werte wurden altersgerecht ausgewertet.

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ausgewogene Ernährung und regelmässigen Sport. Ein Infoblatt 'Gefässanalyse für Ihren Hausarzt' haben wir Ihnen beigelegt.

ODER

Die Befunde zeigen einen grenzwertigen Normalbefund. Die Bilder vom Augenhintergrund deuten auf ein vergleichsweise kleines arterio-venöses Verhältnis hin (arterio-venöses Verhältnis (AVR: 0.81). Wir empfehlen eine Kontrolluntersuchung durch den Kinderarzt zur Beurteilung der Herz-Kreislauf-Gesundheit, eine ausgewogene Ernährung und regelmässigen Sport. Ein Infoblatt 'Gefässanalyse für Ihren Hausarzt' haben wir Ihnen beigelegt.

Wirbelsäulenanalyse:
Ihr Kind ist im Vergleich zu den anderen Kindern eher haltungsschwach. Wir empfehlen Ihrem Kind eine aktive Teilnahme am freiwilligen Schulsport oder in einem Turnverein (z.B. MuKi-Turnen).

Bitte beachten Sie, dass Bewegung für Ihr Kind in jedem Fall wichtig ist. Ihr Kind sollte sich pro Tag bis zu 90 Minuten bewegen. Dies kann erreicht werden, wenn das Kind zu Fuss zur Schule geht, sich viel Draussen aufhält, im Haus genügend Platz für Bewegung zur Verfügung steht und freiwillige Schulsportangebote oder Vereinsangebote wahrgenommen werden.

Falls Sie noch weitere Informationen benötigen, stehen wir Ihnen gerne zur Verfügung. Bitte wenden Sie sich an Katharina Imhof, katharina.imhof@unibas.ch, 061 377 87 36.

Mit freundlichen Grüssen

PD Dr. phil. nat. Lukas Zahner PD Dr. med. Henner Hanssen

Beilage:
-Testbeschriebe
-Infoschreiben für Hausarzt

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Testbeschriebe

Körperfett Bestimmung des Körperfettgehalts mit Fettmesszange sowie eine Messung des Bauchumfangs.	
Blutdruck Blutdruckmessungen mit digitalem Blutdruckmessgerät.	
Gefässanalyse Messung der Durchmesser der Gefässe am Augenhintergrund mittels Fotographie des Augenhintergrunds.	
Wirbelsäulenanalyse Messung der Beweglichkeit der Wirbelsäule sowie Erkennung von Haltungsschwächen (Armvorhaltetest nach Matthiass) mittels Nachfahren der Wirbelsäule mit einem computerisierten Scanner.	

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Infoblatt Retinale Gefässanalyse für Hausarzt

Ziel der Untersuchung

Mit der Untersuchung des Augenhintergrunds werden die Durchmesser der kleinen Arterien und Venen der Retina untersucht. Die Netzhautgefässe sind Teil des Gehirns und liegen in etwa in der gleichen Grössenordnung wie die Herzkranzgefässe des Herzen (~100-250 µm). Die Durchmesser der retinalen Gefässe und das Verhältnis von Arterien zu Venen (AV-Ratio) spiegeln das Risiko für Herz-Kreislauferkrankungen wider. Dabei steigt das kardiovaskuläre Risiko insbesondere bei engen retinalen Arterien und weiten Venen. Mit dieser einfachen Methode kann durch den Blick ins Auge repräsentativ die Gesundheit der kleinsten Gefässe beurteilt werden. Die Untersuchung wir in der Prävention zum Screening des Herz-Kreislaufrisikos und zukünftig zur Verlaufskontrolle medikamentöser und nicht-medikamentöser Therapien (körperlicher Aktivität und medizinische Trainingstherapie) eingesetzt.

Ablauf der Untersuchung

Die retinale Gefässanalyse ist eine Augenuntersuchung ähnlich wie beim Augenarzt. Bei der Untersuchung ist das Weittropfen der Pupillen NICHT erforderlich. Die Untersuchung der Durchmesser der kleinen Arterien und Venen am Augenhintergrund erfolgt nicht-invasiv mit einer Augenkamera in sitzender Position. Es werden zwei digitale Blitzlichtaufnahmen von jedem Auge durchgeführt. Die Bilder des Augenhintergrunds werden danach mit Hilfe einer Spezialsoftware von einem erfahrenen Untersucher standardisiert ausgewertet.

Weiteres Vorgehen (Hausarzt)

Weicht das Ergebnis der Gefässanalyse von der altersentsprechenden Norm ab, sollte eine medizinische Kontrolluntersuchung der kardiovaskulären Risikofaktoren durchgeführt werden (familiäre Vorbelastung, Diabetes, Adipositas, arterielle Hypertonie, Fettstoffwechselstörung u.a.).

Fragen

Bei weiteren Fragen zur Beurteilung der Untersuchungsergebnisse steht Ihnen PD Dr. med. Henner Hanssen (Tel. 061 377 87 43, henner.hanssen@unibas.ch) vom DSBG gerne zur Verfügung.

Literatur

Cheung, N., Saw, S. M., Islam, F. M. A., Rogers, S. L., Shankar, A., de Haseth, K., Wong, T. Y. (2007). BMI and retinal vascular caliber in children. *Obesity, 15*(1), 209-215.

Gopinath, B., Baur, L. A., Teber, E., Liew, G., Wong, T. Y., & Mitchell, P. (2011). Effect of obesity on retinal vascular structure in pre-adolescent children. *Int J Pediatr Obes, 6*(2-2), e353-359.

Hanssen, H., Siegrist, M., Neidig, M., Renner, A., Birzele, P., Siclovan, A., Halle, M. (2012). Retinal vessel diameter, obesity and metabolic risk factors in school children (JuvenTUM 3). *Atherosclerosis, 221*(1), 242-248.

Mitchell, P., Cheung, N., de Haseth, K., Taylor, B., Rochtchina, E., Islam, F. M. A., Wong, T. Y. (2007). Blood pressure and retinal arteriolar narrowing in children. *Hypertension, 49*(5), 1156-1162.

Taylor, B., Rochtchina, E., Wang, J. J., Wong, T. Y., Heikal, S., Saw, S. M., & Mitchell, P. (2007). Body mass index and its effects on retinal vessel diameter in 6-year-old children. *Int J Obes (Lond), 31*(10), 1527-1533.

Appendix E

Curriculum Vitae

KATHARINA IMHOF

Date of birth:	January 5th 1982
Nationality:	Swiss
Profession:	Sports Scientist
E-Mail:	katharina.imhof@unibas.ch
Address:	Sandstrasse 30, 3302 Moosseedorf

PROFESSIONAL EXPERIENCE

Since 2012	**PhD Studies** at the Department of Sport, Exercise and Health (DSBG), Section Exercise and Movement Science, University of Basel
2011-2012	**Teacher** at School Spiegel near Köniz. High School Teacher in Sports, Biology, Mathematics and English

OTHER PROFESSIONAL EXPERIENCE

Since 2012	**Consultant** „fit4future“ Bewegung und Brainfitness, Cleven Stiftung, Baar
2011-2013	**Fitness Instructor** Gym Fit Club, Berne
2010-2011	**Front Desk Attendant** Mike Wiegele Helicopter Skiing, Blue River, BC, Canada
2006-2010	**Clerk** Swiss Ski, National Federation of Ski, Muri (BE)
2006-2010	**Teacher in Substitution in Sports**
2005-2010	**Snowboard Instructor** Swiss Ski- and Snowboardschool Wengen, Wengen
2005-2006	**Student Research Assistant** at MEM Research Center „Institute for Evaluative Research in Orthopaedic Surgery, University of Berne

EDUCATION

Since 2012	**PhD student** within the **PhD Educational Platform for Health Sciences (PPHS)**, University of Basel and the **Swiss School of Public Health+ (SSPH+) PhD Program,** Basel
2004-2010	**Master** in Sports and Science of Sports, **Major** in Science of Biology, **Minor** in Science of History, University of Berne, Berne
2007-2009	**Education in Sports and Biology**, College of Education, Berne
2001-2004	**Veterinary medicine** (first propaedeuticum), University of Berne, Berne
2001	**Matura Typus E**, Wirtschaftsgymnasium Bern Neufeld, Berne

PUBLICATIONS

Imhof, K., Zahner, L., Schmidt-Trucksäss, A. & Hanssen, H. Association of body composition and blood pressure categories with retinal vessel diameters in primary school children. *Hypertension Research,* 1-7. (2016). doi: 10.1038/hr.2015.159].

Imhof, K., Faude, O., Strebel, V., Donath, L., Roth, R. & Zahner, L. Examining the association between physical fitness spinal flexibility, spinal posture and reported back pain in 6 to 8 year old children. *Journal of Novel Physiotherapies*, 5(5): 274. (2015). doi:10.4172/2165-7025.1000274

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Donath, L., Imhof, K., Roth, R., & Zahner,L. Motor Skill Improvement in Preschoolers: How Effective Are Activity Cards, *Sport*, 2(4). (2014).

GRADUATE EDUCATION (ORDERED BY DATE 2012-2015)

Course	Institution	ECTS
Data Analysis in Epidemiology, Prof. C. Schindler	University of Basel	2
Angewandte Gefässphysiologie in Bewegung und Gesundheit, Dr. H. Hanssen	DSBG Basel	3
Fundraising, Dr. A. Degen	University of Basel	1
Statistical Methods for Epidemiology, Prof. T. Lash	SSPH+, ISPM Bern	1
Swiss Epidemiology Winter School 2013, Advanced Survival Analysis, Prof. J. Stern	SSPH+, ISPM Bern	2
Einführung in die Statistik-Software Stata™, Prof. M. Zwahlen	SSPH+, ISPM Bern	1
Systematic Reviews and Meta-Analysis: a Practical Approach, Prof. M. Egger	SSPH+, ISPM Bern	1
Multilevel Modeling: analysis of clustered data, Prof. M. Röösli	SSPH+, ISPM Bern	1
Introduction to Categorical Data Analysis, Prof. G. Lovison	STPH Basel	1
GPP - Global Perspectives Programme	University of Basel	3
Summer School 2013 Charité Berlin, Epidemiology Critically Understood, Prof. O. Miettinen	Charité Berlin	3
Advanced Stata Programming, Dr. J. Hattendorf	University of Basel	1
MOOC PH21x, Health and Society, Prof. I. Kawachi	Harvard University	1
Swiss Epidemiology Winter School 2014, Missing Data Imputation, Prof. J. Carpenter	SSPH+, ISPM Bern	1
PPHS Summer School Physical Activity Basel 2014	DSBG Basel	2
Physical Activity Measurement Seminar Cambridge, Prof. S. Brage, U. Ekelund	MRC Unit Cambridge	2
Writing a Journal Article… and Getting it Published; Dr. J. Bohlius	SSPH+, ISPM Bern	1
GIS for public health, Dr. D. Vienneau, Dr. K de Hoogh	SSPH+, STPH Basel	2
Winter School 2015, Causal Inference in Observational Epidemiology, Prof. M. Hernan	SSPH+, ISPM Bern	2
Good Clinical Practice Basiskurs & Sponsor Investigator, Prof. C. Pauli-Magnus	Universitätsspital Basel	
Workshop with Elsevier: Reviewing and Being Reviewed	Sprachenzentrum Basel, Elsevier	
1 ECTS equals to 30 hours investment time	**ECTS Total**	**31**

TEACHING EXPERIENCE

2015 Angewandte Trainingswissenschaft, seminar, administration and support, DSBG Basel

2015 Informationskompetenz, lecture and seminar, support, DSBG Basel

2015 Supervision Master Thesis "Werden mit den sportmotorischen Tests der Sportcheck Studie die begabtesten Kinder für Talent Eye selektioniert?", Romana Sutter, DSBG Basel

2015 Supervision Master Thesis "Sportcheck: Zweijahresvergleich der sportmotorischen Fähigkeiten der Kinder der 1. Primarklasse im Kanton Basel-Stadt", Claudio Pfister, DSBG Basel

2014 Angewandte Trainingswissenschaft, seminar, administration and support, DSBG Basel

2014 Supervision Master Thesis "Zusammenhang zwischen Ausbildungsstand der Eltern, Einkommen der Eltern, Nationalität und körperlicher Fitness von 6- und 7-jährigen Kindern in Basel-Stadt", Salome Bean-Eisenhut, DSBG Basel

2014 Supervision Master Thesis "Zusammenhang zwischen körperlicher Fitness und Rückengesundheit bei den Schülerinnen und Schülern der Sekundarschule Unteres Furttal", Fabio Moser, DSBG Basel

2013 Angewandte Trainingswissenschaft, seminar, administration and support, DSBG Basel

2013 Supervision Master Thesis "Pilotprojekt Sportcheck – Motorische Leistungsfähigkeit, Übergewicht und Wirbelsäulenparameter bei Kindern der 1. Primarklasse des Kantons Basel-Stadt", Michele Carere, DSBG Basel

2012 Angewandte Trainingswissenschaft, seminar, administration and support, DSBG Basel

EXTRAMURAL PRESENTATIONS

2015 Oral Presentation, Deutsche Vereinigung für Sportwissenschaft Tagung, Potsdam (D)

2015 Oral Presentation, European Youth Heart Study Scientific Symposium, Oslo (N)

2015 Oral Poster Presentation, Schweizerische Gesellschaft für Sport Tagung, Lausanne (CH)

2014 Oral Mini Presentation, European Congress of Sport Science, Amsterdam (NL)

2013 Oral Poster Presentation, Schweizerische Gesellschaft für Sport Tagung, Basel (CH)

GRANTS

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